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Harvey demonstrating the circulation of the blood to Charles I—after Hannah.

Frontispiece.

THE BODY AND ITS HEALTH

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CHAPTER I

HEROIC ADVENTURES

STORIES of adventure and achievement, of mystery and discovery are enjoyed by young and old alike, for they satisfy instincts which everybody seems to possess. Biology and medicine provide many such stories which often have the added appeal that comes from a happy ending and the introduction of the human interest.

Among such stories are tales of long-continued endeavour in face of difficulty and danger, of heroism and sacrifice, of splendid failure and success—in fact tales that run through the whole gamut of the human emotions. Everyone, it would seem, should know something of these stories, but often they remain untold and unknown. If this were not so, discoveries won, sometimes at the expense of the lives of the investigators, would be made more use of, and other adventurers would be stimulated to go on voyages of discovery and so in their turn make contributions to this gradually increasing store of knowledge.

To join in a crusade of health ; to help to stamp out diseases which must disappear under an organised and informed attack ; to bring about the attainment of standards of physical well-being never yet achieved, would be to take part in a movement wholly beneficent. Here is a fight in which the success of one helps rather than hinders that of others, a fight in which people of all nations can unite, and one which will offer to those sharing in it enough of adventure and treasure-hunting to satisfy feelings which exist in nearly everyone.

For such service it is often necessary to have costly equipment and long training, but how much can be done by those without special scientific training can be shown by the work of great social reformers such as John Wesley, Florence Nightingale, Josephine Butler, Octavia Hill and Lord Shaftesbury, to name only a few. There are many ways, too, in which the ordinary individual can take part in this crusade, especially when it is directed to the prevention of disease. If only the laws and rules of health that are known to-day were obeyed and carried out, there would be an immense improvement in the health of the individual and so in that of the community. Dirt, darkness and disease are enemies of well-being which can be largely counteracted by soap, sunshine and sanitation. Litter in streets and public conveyances, untidy and insanitary backyards, the despoiling of the countryside, are examples of a lack of community-sense, and of absence of a feeling of responsibility for the comfort and convenience of others. They constitute a danger to health and an offence to the eye, which under pressure of public opinion could be made to disappear within a very short space of time.

With proper care the incidence of infectious diseases could be very much lessened, and though the common cold has yet to be defeated, even now the number of its victims could be cut down enormously with the co-operation of the individuals suffering from it.

A whole world of adventure and discovery still lies ahead and there are problems to be tackled by united work in which observations collected by anyone, even the humblest, may put the investigators on the right track and so lead to a final success. The remark of a young dairy-maid in Gloucestershire, who, coming to Jenner for advice, said of smallpox, "I cannot take that disease for I have had cowpox," started Jenner on investigations which transformed a piece of folklore into knowledge that could be applied along definite and scientific lines. To-day it is hard to realise what that discovery did for us. Before Jenner's time smallpox was looked upon as practically unavoidable, and people used to advertise for servants who had got over smallpox! In Germany there was a saying, "From smallpox and love few remain free." There are many other cases in which tradition, or the collected experience of generations, has led the way to the disciplined knowledge which has enormously increased its value.

In reading the stories of these adventurers in health and life-saving one shares with the workers their anxieties, discouragements, doubts and excitements, and their happiness when success finally comes, most often only after long and laborious work.

How exciting it is to read of the researches of Pasteur, a man at first doubted and feared by his contemporaries, but finally acclaimed by the whole world, and of the successful and dramatic demonstrations of his results by which he was able to confound his opponents —Pasteur who began his work in a badly-equipped cellar, and carried on in spite of personal illness and the opposition of the medical profession, and who made discoveries which saved the silk, the wine-making, and the sheep and cattle raising industries of France. One shares with him, even in the reading of it, the acute anxiety which gave him sleepless nights when he tried for the first time on a human being the treatment against hydrophobia which he had worked out, and his joy when he knew he had saved from a terrible death the boy who had been dreadfully torn by a mad dog!

How proud we are of the work (following on that of Pasteur) of our own Lister, who was also scoffed at by his colleagues, but who made surgical operations safe; and of whom, at a great banquet in his honour, it was said by the American Ambassador proposing his health, " It is not a profession, it is not a nation, it is humanity itself which, with uncovered head, salutes you ! "

What thrills there are in reading the stories of investigations such as those of Ross, Grassi, Reed, Bruce and their collaborators who tracked down the causes, and so the means of prevention, of malaria, of yellow fever and of sleeping sickness ! To the attack on these diseases came not only the trained mind and the skill of the experimenter, but also the spirit of adventure, of heroism and of sacrifice. The men in Italy who went and slept for many nights on the marshy ground of the ill-omened Campagna in huts made impervious to the mosquitoes, were willing to risk their health in testing the views put forward by Ross and Grassi that the carriers of the infection of malaria were the mosquitoes who had bitten patients suffering from the disease.

In the campaign of 1900 against yellow fever (which had previously defeated the French engineers in their attempt to build the Panama Canal), men and women allowed themselves to be bitten by mosquitoes that had previously bitten persons who were very ill with the fever, in order to test theories as to how infection was conveyed. Most of these developed the disease, and some, alas ! died. These people were all volunteers in a splendid war, a war for the saving of life. A tablet erected to the memory of one of them who was a soldier reads, " With more than the courage and devotion of the soldier he risked and lost his life to show how a fearful pestilence is communicated and how its ravages may be prevented."

To find out whether infection might be conveyed in other ways than by the bite of the infected mosquito, a young medical man and his assistants allowed themselves to be shut up for days in a stuffy little hut, using the beds and linen on which yellow fever patients had lain and died, but with the doors and windows screened so that no mosquitoes could get in. After this they were put into quarantine for twenty days, but they recovered from their ghastly ordeal and did not develop the fever. Other men, however, living in clean and sanitary huts, into which had been introduced mosquitoes that previously had fed on yellow-fever patients, developed the disease.

As a result of these researches and sacrifices it became possible to build the great Canal; and districts in various parts of the world previously looked upon as the white man's grave are now actually health and pleasure resorts.

There is plenty of drama, too, in the story of Banting and Best, the discoverers of insulin. There was one terrible period, after they had been able by their discovery to save the life of a friend who had nearly died from diabetes, when it looked as though they might after all lose him because the technique for obtaining the insulin was not completely worked out. To read of their desperate night and day struggle to procure again the life-saving substance rouses an intensity of emotion which is almost unbearable. What must be the sensations of those two men who know that thousands of men and women owe their health and usefulness to insulin! Their discovery came just in time to save the life of Minot who since then has found the way to save the lives of those suffering from pernicious anæmia, a malady that before his work had always been fatal.

Going back to earlier days, here is an extract from an account of another group of workers who banded themselves together to try and find a liquid which would safely bring unconsciousness to patients and so make possible operations which without such a help could not be attempted.

> " It was the 4th of November, 1847, after a weary day's labour that Dr. Simpson with his two friends and assistants, Drs. Keith and J. M. Duncan sat down to their somewhat hazardous work in Dr. Simpson's dining-room. Having inhaled several substances but without effect it occurred to Dr. Simpson to try a ponderous material he had hitherto regarded as of no likelihood whatever. This happened to be a small bottle of chloroform. With each tumbler newly charged the inhalers resumed their vocation. Immediately an unwonted hilarity seized the party, they became very happy and loquacious. . . . But suddenly there was a talk of sounds being heard like those of a cotton mill louder and louder ; a moment more then all was quiet and then—a crash. On awakening Dr. Simpson's first perception was mental. ' This is far stronger than ether,' said he to himself. His second was to note that he was prostrate on the floor and that among his friends who were about him there was both confusion and alarm."

They repeated the inhalations many times that night, and a few days afterwards Simpson reported that he had administered chloroform to about fifty individuals without the slightest harmful results of any kind. It would indeed be hard to overestimate the importance of the discovery of anæsthetics—we cannot now think of hospitals and operations without them.

Sometimes chance takes a hand. The story goes that a Dutch doctor named Eijkmann, sent out to Java to investigate a disease that was having very serious effects on the people living there, was confirmed in his view that this was due to unbalanced feeding, by detecting symptoms similar to those in the human sufferers, in chickens fed only on samples of rice thrown out after a laboratory investigation.

Another whole set of stories could be told in connection with the application of sunlight and of other lights such as the Finsen lamp to the cure of the different kinds of tuberculosis. Wonderful results are being obtained even in this country, which is not generally regarded as a sunny one, by open-air treatment of children. Then, too, there is the discovery of radium by Madame Curie and its hopeful application to the cure and treatment of certain forms of cancer.

There are so many of these stories that it is hard to stop, but enough has been said to show the interest and excitement that can come from following the work of hese great adventurers in health. Their inspiring example should encourage all of us to keep ourselves mentally and physically fit in the hope that we, too, may play a part, however slight, in the unending fight against disease and death.

CHAPTER II

THE LIVING BODY

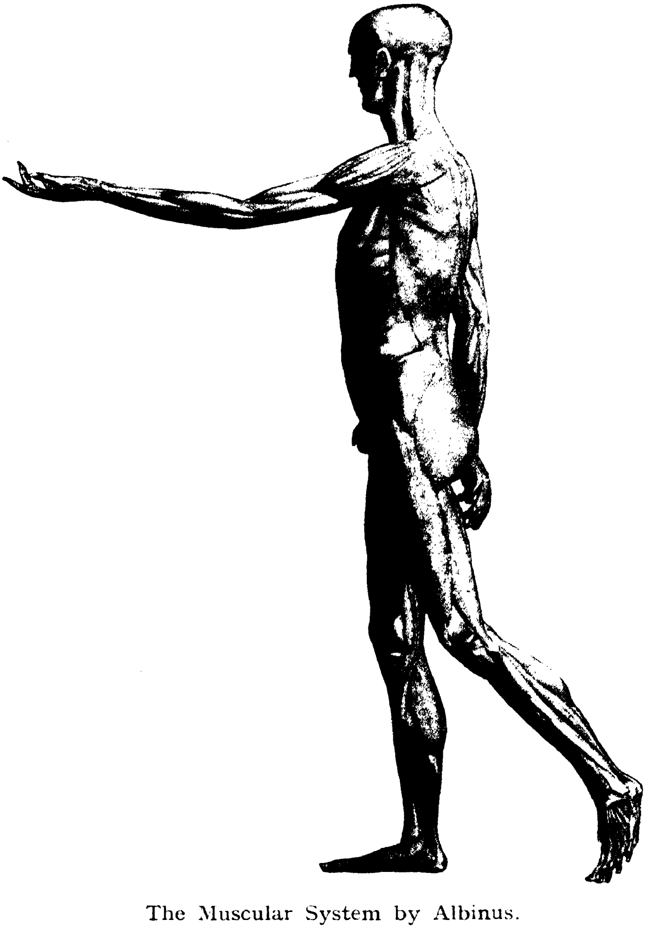
WHEN we look at the world around us we can see a large number of things most of which we could place fairly easily in one of two groups labelled 'living' and 'non-living'. In the living group we should put all the plants and animals, the trees, grass, flowers, birds, butterflies, horses, cats, dogs and ourselves; and into the non-living, stones and rocks, the sea and the earth, the sun, moon, stars, clouds, motor cars, bicycles, engines, clocks, tables, chairs and a host of other things. Why should we separate them like this? What is the difference between the living and the non-living? We are pretty sure that they are very different, and yet it is not easy to say in what way. Is it the power of movement? As a matter of fact movement *is* one of the great characteristics of living things but it is obviously not the characteristic which differentiates them from the non-living. Trees for example do not move in the sense of getting about and yet they are alive; whilst engines, motor cars and aeroplanes may move much faster than we do, or than horses and dogs can, but they are not alive. Is it the power of growing? Crystals grow but are not alive. Is it the power of making heat? Burning coal and gas give out heat but coal and gas are not alive. So we can go through many qualities and powers that belong to ourselves and see that non-living structures possess or seem to possess them. But if we examine closely enough we shall find out activities and powers that belong to living things alone, and of these the greatest number belong to ourselves. We alone of all living things make tools and build machines (thanks largely to that wonderful instrument, the hand) and are thus enabled to do things which other animals can do naturally. We cannot fly like birds, but we can build aeroplanes which make us able to fly higher and faster than birds. We cannot run as fast as many animals, but we can build engines that make us able to travel faster than any animal. Our machines make us able to go under the waters and over the waters. We can build all these things, because inside our heads there is a soft, pinkish-grey, crinkly mass known as the brain, which though weighing only about fifty ounces and made chiefly of water yet gives to mankind marvellous powers.

The human body is indeed a marvellous structure, and yet very often it is badly treated, because its possessors do not bother to find out how to make the best use of all its powers. When everyone has learnt the more obvious ways in which to give the body its chance of living well and also has the opportunity to use that knowledge, the world may be an even more wonderful place than it is to-day, and certainly a much happier one.

The science which concerns itself with these matters is hygiene. In its fuller aspect it is a very large subject, involving knowledge of man's relationships to other living organisms and of his own evolution. But the first necessity for healthful living is some knowledge of the make-up and ways of action of the human body, its development and the influence upon it of environment. This book will concern itself, therefore, chiefly with this particular part of the health problem, though it is hoped that its readers will afterwards go on to make some further study of hygiene in its wider biological aspects.

The human body is made up of a vast number of cells, millions and millions of them, each with its own special work to do. Some conception of their numbers may be gained when it is realised that floating in a drop of blood not much larger than a pin's head there are as many separate units as there are people in London, and that in the blood of a single individual there are more of these units than there have been persons in the whole world since history began. Sometimes the cells act singly as in the case of the leucocytes (or white corpuscles of the blood); but more often the ones carrying out the same kind of work are collected into organs such as the heart, lungs, kidney, liver and many other 'organised' collections of cells. In certain cases two or more organs or parts of the body combine still further to serve some special function, and such a combination is known as a system. Examples of these are the circulatory, the respiratory, the digestive, and the reproductive systems. Before we discuss in detail any of these systems and the way in which they act, it will be useful to consider very briefly the general arrangement and functioning of the body as a whole.

The skeleton and the muscles attached to its separate bones give the body its characteristic shape, and support the whole structure. There are some hundreds of muscles maintaining the balance of the body and making possible its various positions and its thousand-and-one different movements. These muscles, covered with the skin and its appendages, give the familar appearance to the body as we know it. Inside the skull and the backbone—and well protected by them—are the different parts of the central nervous system: the brain (made up of the cerebrum, cerebellum, midbrain and medulla) in the skull, and the spinal cord in the vertebral column. Connecting all parts of this system to one another, and making possible



The Muscular System by Albinus.

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communication between it and the other parts of the body, are the nerves carrying messages to and from the central nervous system.

The muscles and nerves are very closely connected, and in the living body practically no muscular action takes place except as the result of messages sent from and to the muscles by nerves. Because life is so largely maintained by movements of all kinds the two together are sometimes called the master tissues of the body. The whole of the rest of the body may then be regarded as being used to serve these tissues and to enable them to carry out the will of the individual. Having very obviously a special importance to the work of these master tissues are those other parts of the body which give information as to what is going on in the individual's environment. It is vitally important for him to know whether he is in favourable or unfavourable surroundings so that he may stay in the one or get out of the other. This information bureau, as it might be called, is made up of the various sense-organs, sometimes called the organs of special sense: the eyes, ears, nose, mouth and skin. These respond to every kind of change in the environment and pass on the information to the central nervous system, where it is received and sorted out, from there messages are sent out as a result of which appropriate action is set in motion. All these parts, to keep going, must have food and oxygen; and these are brought to them by the blood, which is circulated through the body by means of the heart and blood-vessels in such a way that every tissue and every cell receives what is necessary for its appropriate function. The supply of oxygen is secured by the respiratory system, which also helps to get rid of an excess of carbon dioxide—one of the products of the burning or oxidation of foodstuffs. This burning, going on in all parts of the body, sets free energy which is made use of, partly in the form of work and partly as heat.

The foods taken in by the mouth have to be specially prepared before being absorbed into the blood-stream. This is done by the alimentary system. An important organ, the liver, is largely concerned with the proper preparation of the foodstuffs, for use in the tissues, after they have reached the blood-stream. Some organs are specially concerned with the getting rid of waste material. The kidneys help to do this, but they also play an important part in keeping the blood in just the right condition for the cells. Other organs help to control the growth and general activity of the body.

Finally there are special organs whose work it is to produce the cells in the two bodies, male and female, which by coming together start a new life and so carry on the race.

CHAPTER III

THE SKELETON

THE nerves and muscles, we have seen, can be described as the master tissues of the body. Together they are responsible for the movement of the body from place to place, and for the skilled movements characteristic of the form of animal organism seen in man. For all these a jointed framework is necessary and this is provided by the skeleton. Without our bones we should be of very much the same consistency as a raw egg and so would tend to collapse under our weight and spread out much as an egg does when taken out of its shell. The skeleton also protects specially delicate and valuable parts such as the nervous system and certain of the sense organs. It consists of more than two hundred distinct bones of various shapes and sizes which extend from the crown of the head to the sole of the foot. The separate bones are in contact with one another in such a way that they make a continuous framework, and where they meet one another a joint is made. Some joints are movable and others are not. Each movable joint consists of a smooth, lined cavity, generally supplied with cushions of cartilage (gristle) and a certain amount of fluid which enables the bones to glide easily over each other without any friction. Sometimes when joints are injured there is an accumulation of this fluid, as in ' water on the knee.'

The central pillar of the framework is the spinal column or backbone (*Fig.* 1) to which directly or indirectly all the rest of the bones are attached.

The spinal column is made up of thirty-three separate bones, the vertebræ, piled one on top of the other, separated from one another by pads of cartilage or gristle and held in position by strong ligaments. Each vertebra (*Fig.* 2) has at the back an arch, and the arches are placed above one another

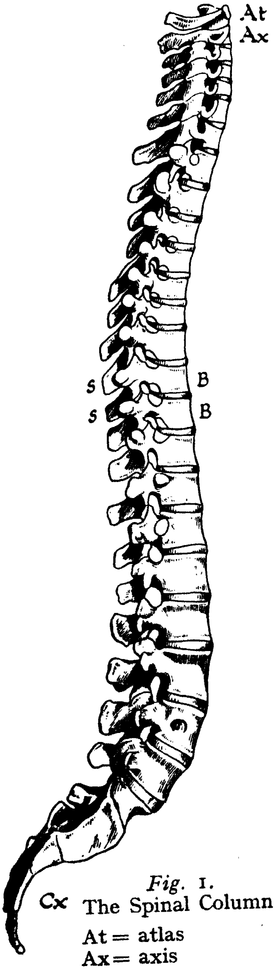

Fig. 1.
The Spinal Column.

At = atlas
Ax = axis
S = spinous process of a vertebra
B = body of a vertebra
Cx = coccyx

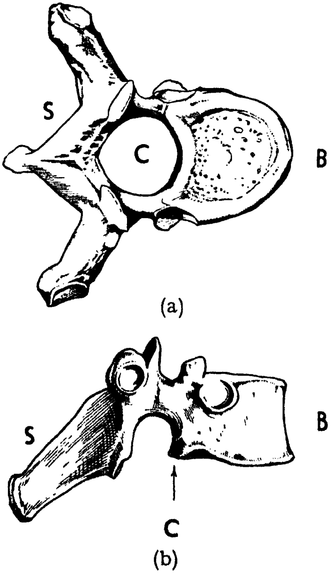

Fig. 2: A vertebra viewed (a) from above, and (b) from the side.

B = body
C = canal
S = spinous process

in such a manner as to make a continuous canal in which the spinal cord is lodged.

On the top of the spine is balanced the skull. It is made up of two parts: the brain-case, consisting of several bones fitted very closely together to make a round closed cavity in which the brain is securely packed and protected; and the face, in which there are light bones with cavities for the eyes, nose and mouth. Lower down, the twelve pairs of ribs branch from the spine, and curve round each side of the chest to meet the sternum, or breast bone. Applied to the chest on each side is the shoulder-blade joined to the sternum by the collar-bone. Into the shoulder-blade is fitted the upper bone of the arm, the humerus; to that in turn at its lower end, where the elbow joint is formed, are fitted the bones of the forearm, the ulna and the radius. To the lower end of the ulna are attached the wrist-bones, and to them in turn the bones of the hand and fingers.

At the lower end of the spine is found the pelvis, a bony ring with sides sufficiently deep to form a capacious cavity. To the pelvis on each side is joined the upper bone of the leg, the thigh bone or femur. The femur is attached to the main leg-bone, the tibia, by the knee-joint, which is protected by the knee-cap (shaped like a limpet-shell and about the size of a five-shilling piece). The tibia is roughly triangular in shape and its front edge forms the shin. The second bone of the leg, the slender fibula, clings to the tibia at its ends rather like the pin to a brooch. These two bones swell at their ends to form the ankle to which are attached the bones of the heel and foot and toes.

The different joints of the skeleton allow of very varying amounts of movement. Those allowing the greatest range are the gliding-joints found in wrist and ankle; the ball-and-socket-joints at the shoulder and hip ; the hinge-joints seen in the jaw and in the elbow-, knee-, finger- and toe-joints ; and a ring-joint where the upper end of the radius joins with the ulna. In the spine there is little movement of the vertebræ upon one another, but the whole arrangement of bones and joints alternating throughout its length gives it an extraordinary combination of strength with elasticity, so that the body can be bent backwards or forwards or swayed from side to side with ease and grace. The skull has a very considerable range of movement. It rests on the top vertebra (the atlas), which rotates round a projection from the second vertebra (the axis). The extent and kind of movement of the different joints can best be found by experiment and observation.

Bones are wonderful structures, and it is important to realise that in the living body they also are living. The phrase ' as dry as a bone ' or ' bone-dry ' only really applies to dead bone. A bone certainly does contain a great deal of lime which gives it hardness, but it has animal matter too. The two parts are very closely mixed, as can be proved by two simple experiments. If a bone is heated so as to burn away the animal matter, it will still be the same shape though it will have become brittle and fragile. On the other hand if it is treated with acid which dissolves away the mineral and leaves the animal matter, it still has its original shape, but now is soft and pliable. Like other tissues the bones are supplied with blood-vessels and nerves, and have to be continually fed. Solid bone is heavy because of the lime in it ; and to lessen their weight most of the long bones are hollow, the central space being filled with bone-marrow. This does not lessen their strength, for engineers have found that a hollow steel rod is in many ways as strong as a solid one of equal diameter. Bones are remarkably strong. For example, it was found that a cubic inch of bone

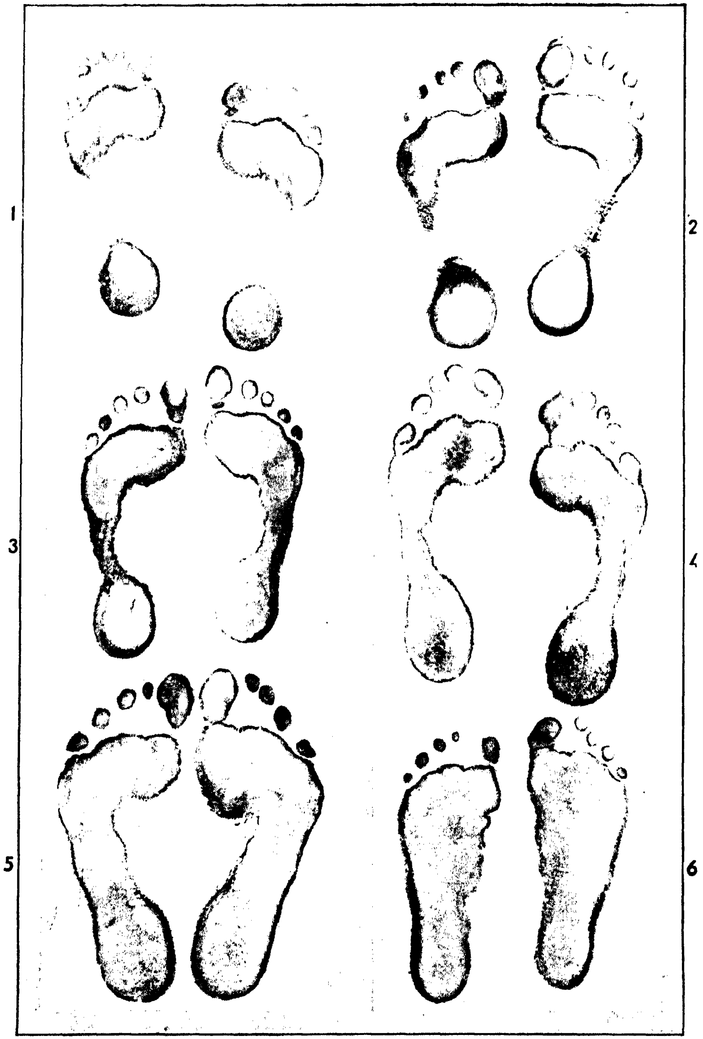

Fig. 3 : Footprints illustrating the development of flat-foot.

Made by a school-boy during routine medical inspection by Dr. R. J. E. Hanson, F.Z.S., Cornwall County Council.

To face page 25.

weighing about one-seventh of an ounce taken from a thigh-bone could support a weight of 400 lbs., without giving way.

Because they are alive, bones can repair themselves; and a broken bone, if put into the right position, will grow perfectly well and strong. But because they are alive, they can also be abused. Using them badly makes them get out of shape, and wrong feeding will prevent them growing properly. It is important to stand and sit properly. A person who sits in a stooping position will soon get round shoulders; and standing on one leg will push up the hip on that side, so that the pelvis slants instead of being level, and a lateral curvature of the spine will be produced. Very few people have exactly the same measurement on both sides from the waist to the ground because they have rested their weight too much on one side. When carrying heavy bags and piles of books, the load should be changed from one hand to the other fairly frequently, and not always carried on the same side. Conditions which involve keeping the body in an unnatural position for long periods affect the skeleton. A jockey, for example, is often bow-legged; and other occupations are responsible for characteristic deformities.

A condition known as flat foot (*Fig.* 3) in which the arch that is made by the bones of the foot has given way more or less, is much too common. It makes walking fatiguing and is often the cause of aching feet. It is found in those who stand much and adopt a faulty position, and in those who wear badly shaped or too heavy shoes. In standing the feet should be nearly parallel to one another or even with the toes slightly turned in; in walking too, the foot should be kept straight and the heel put down first. High heels (particularly those of the peg-top variety) bring the pressure of the heel into the wrong part of the foot for proper balance, and so spoil the foot and produce an ugly and ungraceful carriage. To strengthen the arch, walking along a chalk-line or along the edge of a board in the floor are good exercises, as are also skipping, and heel-raising with the toes touching and heels apart.

It is of the greatest importance to prevent wrong postures and strain in babies and quite young children, whose bones are not yet hardened and can therefore very easily be bent out of shape. The best food for hardening bones and developing them properly is milk, as it contains the two mineral substances lime and phosphorus, which are absolutely necessary for the building up of good bone and contains them in just the right proportions. Both whole milk and skim-milk will give these minerals, but only whole milk will provide the vitamin which is necessary for the laying down of good hard bone. Much more will be said of this vitamin in the chapters on diet. Babies, of course, live mainly on milk; but some milk (at least a pint a day) should be included in every person's dietary. This is particularly necessary in the case of children. This does not mean that it must be drunk as milk; some of it may be in puddings and custards, or in tea or cocoa or soups. As an addition to whole milk, skim-milk is a most valuable food, helping children to grow both in weight and height. A well-built and well-shaped skeleton gives all the soft organs of the body the best chance to grow in the correct position and thus function properly. Milk is important, therefore, for health, but it also counts for much in giving a good carriage and so a good appearance.

CHAPTER IV

MUSCLES

THOUGH the bones are necessary for effective movements of the body, it is the muscles which actually carry them out. Muscles are things to be respected and treated well. When properly developed they give beauty of form and action; and, in man, they are responsible for three very characteristic attributes—the power of speech, the skill of the hand and the expression of the face. The muscles used in these and many other movements are called *skeletal,* because of their attachment to the bones of the body, and *striated* or *striped,* because of their appearance under the microscope. Besides these there are two other groups of muscles: the *unstriped,* or *involuntary,* found in the walls of the blood-vessels and of the alimentary canal; and the *cardiac* found as their name indicates only in the heart.

The skeletal muscles form what is known as ' flesh ' and when we eat meat we are eating the muscles of the various animals used for food. These muscles are joined at their ends by strong tendons to the different bones of the skeleton—such tendons can be felt in the wrist and behind the heel. Each big muscle is made up of a number of minute threads or fibres, each thread being really an elongated cell an inch or less in length. Under the microscope it looks as if it were made up of alternate dark and light discs piled one above the other, as black and white draughts might be (*Fig* 4). Striation seems to go with the power of making rapid contractions. Our own muscles can only make about ten or twelve separate contractions a second; but the wing-muscles of insects—which show striations very clearly — can contract very rapidly. A bee can move its wings 440 times a second, and when it is angry at an even faster rate.

Each muscle-fibre has its own nerve-fibre by which it receives messages, and groups of them can send messages of sensation to the central nervous system. In between the fibres is a very rich network of capillaries. It has been calculated that if the capillaries of the muscles of a man could be placed end to end they would reach two and a half times round the earth!

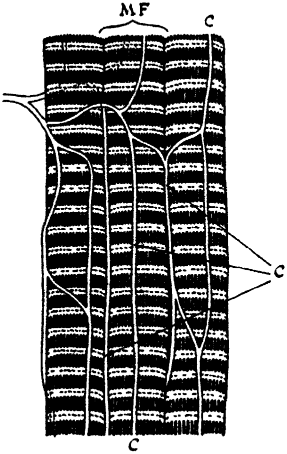

Fig. 4: Showing muscle-fibres and capillaries highly magnified.
C = capillaries
MF = muscle-fibre

The involuntary muscle-fibres (also called unstriated or unstriped because they do not show the horizontal markings), are only about 1/600 inch long. They are joined together in flat bundles by a kind of cement-like substance; and, unlike the striated fibres, seem to be able to contract rhythmically on their own. They are supplied with two sets of nerves, one of which can increase and the other decrease their activity. The cardiac fibres, or fibres of the heart, are also microscopic in size but they show a cross striation and contract more quickly than the unstriped. Like the unstriped they contract rhythmically, and have two sets of nerves, one of which can stop the heart or make it go slower, while the other can quicken its rate or increase its force. These two kinds of muscle are obviously essential to life since they carry out actions without which we could not live. If the heart stopped the circulation would cease, and if the muscles of the digestive tract ceased contracting we should not be able to digest our food. But more can be learnt of the ways in which muscles act by studying the so-called voluntary ones. We say so-called because though we can decide to sit or stand or throw a ball ; we cannot consciously bring about the contractions of the particular muscles necessary for any of these movements nor can we by will contract them in the right order and to the right extent. This correct grouping and sequence of contraction of the muscles is spoken of as co-ordination. The human hand is a striking illustration of what can be done by co-ordination. It is an intricate business carried out by the nervous system with the help of a succession of messages from and to the muscles. On it depends to a large degree the dominance of man in the animal world. Neither bulk nor strength is as desirable as co-ordination. Bulk for bulk the muscles of the ant are many times stronger than those of man. Large muscles are useful for violent actions and for feats of strength but do not seem to be necessary for skilled or prolonged activity.

An example of co-ordination is seen in the balancing of the actions of groups of muscles which, because they act in opposition to one another, are called antagonistic muscles. No matter what position the body adopts, these muscles are in action all over it, maintaining balance and posture. Rest or apparent absence of movement may mean a balance between two opposing sets of muscles. In standing, for example, a balance must be maintained between the muscles which would bend the body forward (the flexors) and those pulling it back (the extensors). A person learning to skate or ride a bicycle, or a baby tackling the great adventure of walking, is at first slow and awkward and uses an unnecessary number of muscles, but once the correct balance and co-ordination of movement have been learned these actions become very smooth and almost automatic, as does any constantly-practised action. ' Practice makes perfect ' says the adage; but if the action be practised in the wrong way, practice makes *imperfect*. For this reason it is important to get the muscles as far as possible into good habits. They will unfortunately quite easily learn bad habits, and when a bad habit has been acquired it is very difficult to unlearn it and replace it by a good one.

Another example of the constant succession of messages passing between nerve and muscle is found in what is known as *muscle-tone*. By means of a series of messages, coming to the muscles from the nerve-centres, at the rate of about twenty to thirty a second, healthy muscles are kept in a slight state of contraction. Only a limited number of the fibres of which the muscle is made-up are in contraction at the same time: they work and rest in shifts so that the muscle as a whole does not become tired. We are quite unconscious of these messages, but they are necessary for effective muscular action. When an individual is tired—and sometimes also in hot weather and in hot climates—the messages are faint and the muscles become flabby and toneless.

The braced-up feeling produced by a cold bath or a cool breeze is due largely to an increase in such messages with an added tightening of the muscles. A 'slack' person often has 'slack' muscles, due perhaps not so much to fatigue of the muscles as of the nervous system, which cannot then send out the necessary messages to the individual muscles or groups of muscles.

Everyone knows that people are apt to become clumsy when they are tired or cold or improperly fed. A certain amount of rest and warmth and sleep are absolutely necessary if the nerves, and so the muscles, are to be kept efficient.

When a muscle works it is said to *contract* because often there is a shortening of the muscle which changes its shape but not its volume. If the arm be flexed the shortening and widening of the biceps which pulls up the forearm can very easily be observed. But sometimes muscles work hard without shortening, as in carrying a heavy bag with the arm fully extended. This kind of action is still called a *contraction.* The energy for the contraction is obtained from burning sugar very much as the steam engine gets its energy from burning coal. Most of the energy takes the form of heat, but about a quarter of it can be converted into work. This is quite a large proportion, since a good locomotive engine only converts about twelve-to-fifteen per cent. of its energy into the form of work, though a Diesel engine can do much better. An ounce of sugar when burned gives enough energy to produce about 350,000 ft.-lb. of work; but, since only about a quarter of this will be available for work, some 86,000 ft.-lb. of work can be done for every ounce of sugar burned in the muscles. By using an ounce of sugar in the body a man weighing 140 lb. would be able to climb 600 ft. Persons doing hard muscular work therefore need a lot of sugar or of starchy foods which will be turned into sugar in the body.

When the sugar is broken down in the muscles, it makes an acid called lactic acid (very like the acid which appears in the souring of milk), which is afterwards oxidised to carbon dioxide. If either of these accumulates in the body, fatigue sets in, as it does if all the stores from which the muscles get their sugar are used up. In the body the circulating blood takes away the waste substances from the muscles and brings them the necessary oxygen and food ; so that whether a group of muscles is fatigued or not will depend, not only upon the amount of work they do, but also upon their supply of blood. That is why work done in a cramped position is so fatiguing. More work can be done in walking or in running than in any other exercise because the position of the body then favours a good circulation. Think of the difference in muscle-fatigue between walking for two hours with free movements and writing an examination paper for two hours with the hand held in a more or less fixed position.

Another way to prevent muscle-fatigue is to have suitable pauses in the work. An Italian physiologist named Mosso showed that a finger made to work until it was so exhausted that it took two hours to recover, would only need a rest of a quarter that time if it was only allowed to do half the amount which had exhausted it ; and if the finger were worked at such a rate that recovery could take place after each contraction, then it could go on for hours. The novice climbing a mountain with a guide feels at first that the guide is going very slowly. But he will find, however fit he may be physically, that he will be exhausted long before the experienced climber is at all fatigued.

One of the most striking examples of this proper use of a rest-pause is seen in the heart which is able to go on beating steadily all through life, about seventy to eighty times a minute, by having a rest-pause after each contraction during which it is able to get rid of the waste and to renew its stores. A man sprinting for a hundred yards can in a few seconds exhaust himself much more than in running for a long time at five miles an hour. The second wind that comes in games probably means that the circulation has been so speeded-up that the blood can convey oxygen from the lungs to the muscles at a pace which will allow the repair-processes to keep pace with the breakdown changes.

Posture is very important too in ordinary life in keeping the muscles properly balanced and properly supplied with blood. No one posture should be maintained too long or the circulation will slow down through some of the muscles. Lessons or work done sitting should be interspersed with a period of free movement. Instinctively people who have been still for a long time will get up and ‘ stretch ’ themselves.

The moral of all this is that it is not economical to work to a state of exhaustion and that a rest at a suitable time will very much increase the capacity for work, as also will a free circulation of blood through the muscles.

CHAPTER V

NERVES

As far as we know the muscles in the body never contract without having received a message or impulse from a nerve. These messages will not be sent out properly unless other impulses come up from the muscles to the brain giving information about their condition. Since muscle and nerve, then, are so closely associated in carrying out actions—and actions mean life—to understand clearly how the muscles act we must know more about nerves.

The word ‘ nerve ’ has many associations. It is sometimes used as a term for courage or audacity (both qualities which argue a co-ordinated and efficient action of the nervous system). In the plural it generally stands for the reverse ! In the physiological sense, the word makes us think of slender, white, glistening threads with independent existences, capable of carrying messages up and down the body and making connections with the central nervous system. A nerve-fibre is not really an independent structure but is an outlying part or branch of a nerve-cell. Sometimes it is short and sometimes long. In the larger animals nerves may be yards long and even in ourselves they may be two or three feet in length. The nerve-cell is really the essential element of all the nervous tissues. Its form varies in different parts of the system. It is made up of a cell-body containing a *nucleus*, inside which is a still smaller body called a *nucleolus* (*Fig.* 5) ; and it has two or more branches.

In the cell-body are small masses or granules which by their reaction to special dyes or stains enable us to discover whether a nerve-cell is fresh or fatigued, healthy or injured. One slender process called the ***axon*** is the essential part of the nerve-fibre which carries the message from the cell. A little way from the cell this often takes on a fatty, insulating sheath called the ***medulla,*** which gives the medullated nerve-

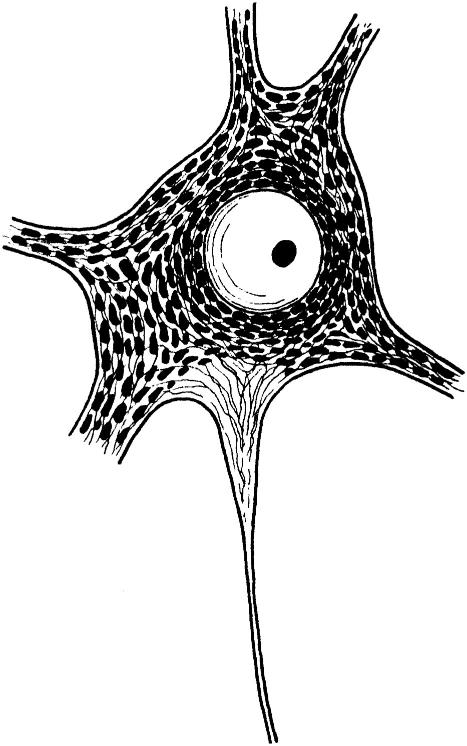

Fig. 5
Nerve-cell showing nucleus, nucleolus and granules.

fibre its characteristic whitish appearance. The axon always carries impulses *away* from the cell. The other branches which are called *dendrites* (sing. *dendron*) (*Fig.* 6), do not as a rule possess a medullary sheath, and they always carry their impulses *into* the cell. The whole structure, cell, outlying nerve-fibre, and dendrites, forms what is conveniently called a *neurone.* Impulses are passed across the cell in one direction only—*from* the dendrites *to* the axis-cylinder, or axon. That is to say, the nerve-cell behaves as though it were a valve. The axon may carry its messages to a muscle-fibre, to make it contract; to a gland to make it pour out its special secretion; to other parts and organs of the body; or it may pass its message on to another cell. In the case of the last action, the end of the axon breaks up into fine branches which make contact with the branched dendrites of the second cell. The junction of these branching processes is called a *synapse.* The valve-action of the cells and the formation of synaptic

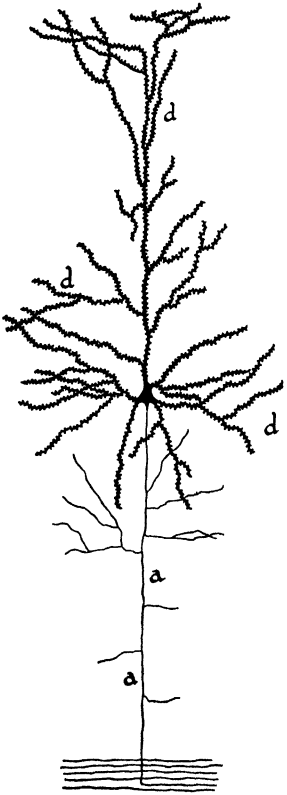

Fig. 6: Nerve-cell showing cell-body and processes.
a = axon with branches
d = dendrites

junctions make it possible to link together without confusion the myriad messages sent to and fro between the cells of the body and the cells in the central nervous system.

The work of a nerve-fibre is to take messages and pass them on. As far as the nerve itself is concerned the impulse can travel in either direction, just as an electric current can pass in either direction along a wire ; but when the impulse gets to the cell it is only passed on if it comes in by the right door, so to speak—that is, by the dendron. Those nerves whose impulses are passed across the cell are called *afferent* nerves, those which carry it away from the cell are called *efferent.*

The axons of a number of cells in the central nervous system make connection with nerve-cells which are grouped together outside the central nervous system. These cells and connections form what is known as the *autonomic* or self-regulating system. The fibres from some of these groups of cells do not take on a fatty sheath after leaving the appropriate cell. They form the *sympathetic* system, so called because it was supposed to regulate the emotions. Nerves from this group do largely supply the involuntary muscles of the body and the cardiac muscles, which common experience teaches us are much affected by emotions.

The autonomic system as a whole acts as a kind of subsidiary centre carrying on many activities without sending messages about them up to the brain. The digestive movements, for example, are controlled in this way though if necessary the higher centres can step in and take control. This means a saving of time and effort rather like the delegation of some of the local work from a head office to a subordinate one, where, however, in any emergency, connection can be made between the two and control assumed by the central office.

An impulse travels along a nerve at a rate of about 150–350 feet a second: quite a good rate, but not one which justifies anyone in saying that something was done 'as quick as lightning' or 'in a flash,' since light travels at the rate of 186,000 miles a second. The successful competitors in the great Melbourne Centenary Air Race, averaging about 220 miles an hour or 320 feet a second, flew at very much the pace at which an impulse travels along a nerve. Actually this rate is sufficiently slow to make it take perceptibly longer for a message to travel along the length of nerve found in a tall person than in a short one: so that, other things being equal, small people should be, as they often are, quicker in response than tall ones.

A remarkable property of nerve-fibres is that they never seem to show any signs of fatigue. The passage along them of impulses does induce some slight amount of chemical breakdown, with a consequent production of waste substances, as in muscles. But, unlike muscle-fibres, nerve-fibres will never allow themselves to be 'hustled,' to to speak. They only pass a second impulse along when they have cleared up from the first. If that is so, why do people talk of nervous fatigue? Is this imaginary or real? It is real, very real, because this same clearing-up does not seem to take place so successfully in the cells. Breakdown-products do accumulate there and at the synaptic junctions; and then the impulses cannot get across smoothly and efficiently. It is very important, therefore, not to fatigue the cells. The best way of resting them is sleep. During sleep the fewest possible messages are coming in, so there is time for washing away waste materials and bringing up fresh oxygen and food material. Nerve-cells are extremely susceptible to a lack of oxygen; and if they are completely deprived of it for only three or four minutes, they are so damaged that they never recover their full activity.

People who—from lack of hæmoglobin in their blood or from a poor circulation, or from breathing impure air—do not get enough oxygen to their nerve-cells, cannot do good brain work, or indeed good work of any kind. They are often listless and apathetic and not very intelligent, and sometimes suffer from headaches and sickness. Such people change for the better very rapidly and amazingly directly the cause of the poor supply of oxygen is removed. When there is too little oxygen there is often too much carbon dioxide; and this, too, adversely affects the nerve-cells. If enough of it were collected the cells would be anæsthetised and all their activities held up. Other anæsthetics, such as ether, chloroform and alcohol, act in very much the same way.

The nature of the impulse which passes along a nerve-fibre is probably always the same whether it goes along an afferent or an efferent nerve: in fact, sometimes, if two different nerves have been cut and joined together wrongly they reverse their actions. Yet we know that stimulation of different nerves leads to very different effects. This is the case because the nature of the effect is determined by the destination of the impulse. If it ends in the foot, the foot will move; if in the hand, the hand will move. Light falling on the eye stimulates a sensation of light; but a blow on the eye will also give rise to the same sensation if the impulse travels up by the optic nerve, because it arrives at the part of the brain which gives rise to that particular sensation however it is set in action. The story is told of an Irishman who summoned a man for an assault which he said took place on a pitch-black night. When the magistrate asked him how he recognised the man if it was absolutely dark he said, "Sure, your honour, I saw him in the flash of light that came when he struck me."

If an arm has had to be cut off, for a long time after the operation any stimulation of the nerves in the stump is felt as coming from the limb which has been amputated. Something, too, depends upon the place at which the impulse is received. A tuning fork vibrating against the fingers gives an impression which is felt in the fingers as vibrations; but the same vibrations falling on the ear through the air, give the impression of sound. A hair at the back of the throat may cause almost convulsive movements of every muscle in the body in an attempt to move it, but on the back of the hand it may have little or no effect.

Another important point about a nerve-fibre comes from the fact that it is an outlying part of a nerve-cell. If the fibre be cut across, and completely separated from the cell, it breaks down and disappears or degenerates. But the cell can send out a new fibre, and if this new fibre can find the path of the old one it will grow along it and arrive at the original place, and there will be no permanent breakdown or alteration in the capacity of the individual. That is why even quite bad cuts and wounds often do not cause permanent loss of sensation or muscle-power.

CHAPTER VI

THE CENTRAL NERVOUS SYSTEM

ONE of the most striking characteristics of human beings is that each one is a ‘ person.’ When we stop and think about it, we shall probably feel that it is little short of a miracle that out of all the innumerable units of which the body is made it is possible for something so definite and distinctive to be produced. This marvel of ‘ integration ’ is brought about chiefly by the central nervous system. In it are co-ordinated and related to one another, the various messages carried to and fro from all parts of the body by the nerves, which constitute—as we have seen—its great messenger-service. For this reason it is regarded as the most important part of the body ; but, important as it is, it must never be forgotten that it can only express itself through the rest of the body. The more efficiently the rest can function the greater chance this system will have of being used to its fullest capacity.

Without the central nervous system, the ‘ person ’ would not exist, and so the system is well protected by being packed away inside the skull and the backbone. It is still further protected by three delicate but tough membranes which are found between it and the bones and by a certain amount of fluid found in this space which acts as a kind of water-bed, shielding it from the jarring effect of sudden movements. The system consists of the brain, made up of the cerebrum, the cerebellum and the medulla, inside the skull, and the spinal cord, a continuance downward from the brain, inside the vertebral column.

The Spinal Cord.

In any large organisation there has to be a certain amount of delegation of authority and of division of labour if the work is to be carried out quickly and efficiently. In a big retail business, for instance, there would be a great deal of delay if every order had to go to the head office before it could be dealt with. The same sort of division of labour is found necessary in the central nervous system. The outermost part or cortex of the brain is the final governing part. Controlled by it, but capable, if necessary, of acting independently of it, are centres at different levels which have a good deal of autonomy.

Actions which are carried out through such centres, independent of the will, and often without giving rise to consciousness, are called reflex actions.

If the foot of a person lying asleep is gently tickled, so that he does not wake, the foot will be withdrawn ; though if he were to wake many other and quite different things might happen ! In the first case consciousness is not involved because the different impulses coming in by the cord do not get up to the cerebral cortex, and such actions which take place through centres in the spinal cord are of the kind called reflex actions. There is no element of choice in a reflex action ; given a certain stimulus under similar conditions, the response will always be the same. In the second case, when the messages get up to the higher centres, the levels of consciousness, it is clear that the very important element of choice comes in. The movement may be a withdrawal of the foot very much as in the reflex action, using the same muscles and the same nerve-paths ; or the movement may be completely prevented by the exercise of self-control. In this latter case the normal change-over from the afferent impulses coming from the foot to the efferent ones which would result in its withdrawal has been stopped or ‘ inhibited.’ This inhibition of withdrawal may have been accompanied by a co-ordinated movement, of the same muscles grouped in quite a different way, or of other muscles, for purposes of offence or of defence.

In general, reflex actions have a protective or defensive effect ; and the fact that they can take place without wasting the time that would be necessitated by a further nerve transmission, and without, so to speak, ‘ troubling the brain for instructions ’ is clearly to the advantage of the individual. This protective effect is shown in many examples of reflex action ; the withdrawal of the foot or the hand from a painful stimulus such as a prick or a burn ; the closing of the eyelids if a foreign body approaches the eye ; the outpouring of saliva when acid gets into the mouth or at the thought of savoury foods ; the contraction of the pupil of the eye in a too bright light. These actions, as will be seen, may involve the central nervous system at all its levels ; but their essential features can be studied very well in actions carried out entirely at the level of the spinal cord. It is important to understand how they are brought about, for they form the basis not only of unconscious protective actions but probably of every kind of action, even those involving consciousness, and they certainly form the basis of what is described as ‘ getting a habit.’

The spinal cord, as we have seen, runs down in the vertebral canal. It is made up of two kinds of nerve matter, grey and white. The grey consists of nerve-cells and their processes, and the fine branching endings of nerve fibres. The white matter is made up of medullated nerve-fibres which carry messages up and down the cord; making possible, connection between all parts of the body and the spinal cord, and between the different levels of the cord, and the brain and the cord. At the level of each vertebra a pair of nerves, the spinal nerves, leave the cord and emerge through gaps left between two neighbouring vertebræ, one on either side. There are thirty-two such pairs. Each nerve of the pair is made up of two parts; one from the front of the cord called the anterior root, and the other from the back, the posterior root. The anterior root fibres have their origin in cells in the front part of the grey matter of the cord; the posterior are the fibres of some nerve-cells found on the posterior root *ganglion*, a mass of cells and fibres found on the posterior root quite close to its junction with the cord.

The anterior root carries impulses out of the cord, and therefore its fibres are efferent; the posterior root carries impulses into the cord, thus its fibres are afferent; together the two roots give a way out and a way in.

Now let us consider the simple reflex of the tickled foot. The message starts at the skin, where it is taken up by some touch nerve-endings and passes up to the cord by nerves supplying the foot, which, because the messages are afferent (or *towards* the brain), go in by the posterior root. The nerve bringing the impulse into the cord divides, and one branch may carry the message right up to the seat of consciousness (as it would if the person were awake) while the other will pass it on to a cell in the grey matter of the cord at about the level of entry. The impulse enters this cell by its dendrites and passes out by its axon, which may go to another nerve-cell, or may be the actual efferent nerve which will pass out by the anterior root to some of the muscle-fibres involved in the withdrawal of the foot. All these parts are essential for a reflex action. The receiving station or receptor, the afferent fibre bringing the message in, the cell with its synapse (the junction between the branched axon and dendrites), and finally, the efferent fibre to carry the message out and the effector end organ (*Fig.* 7).

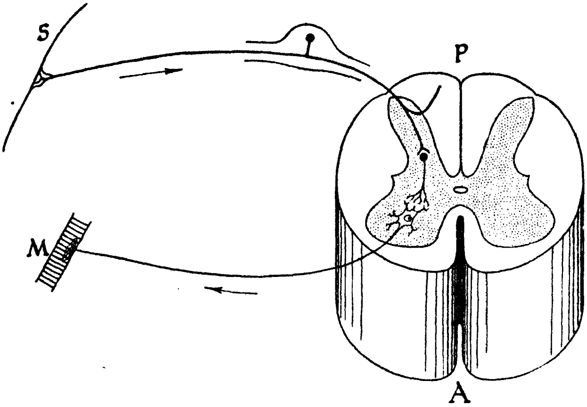

Fig. 7 : Section through spinal-cord, showing grey matter and white matter, and the path for a simple reflex.

A = anterior surface of cord
M = Effector end organ (muscle-fibre)
P = posterior surface of cord
S = Receptor end organ (skin)

A message coming in by an afferent nerve at one level may cause effects in the body at practically any level. Information brought in by the eye can cause actions and effects in all parts of the body. The same muscles used in the withdrawal of the foot in the simple reflex mentioned could be used as a result of many other stimuli coming in from other parts of the body. To fit in with this, there are very many more afferent fibres in the body than efferent. The message to bend or extend the knee, whatever its starting-point, must always finally arrive at the same muscles. The nerve which carries this final message is called the *final common path.* A person going home will always go up his own path wherever he started from. Telephone messages coming into a house, wherever they started from, come in by the private wires to the final receiver.

But as there are so many ways in which an impulse coming into the cord or into the brain can be passed on, it is obvious that the body must learn which are the right paths to follow to bring about any particular result. At first the impulses spread widely and a great many unnecessary muscles are brought into play. In learning to write, the tongue, the lips, and even the body are sometimes used to help the hand. But when the movements have been practised, the hand-muscles hold the pen or pencil and guide it in the right direction with very little effort. In learning to ride a bicycle, or to skate, what a waste of muscle-energy there is at first ! But finally, when the right paths are well laid down and the right combination of muscles is used, how effortless it becomes. The movements are scarcely thought of, they become reflex and automatic. Everyone knows how difficult it is to get out of a habit which has become almost part of daily routine unless concentration is applied or until the new habit is developed. On New Year's Day people are likely to write the correct date ; but a few days later, when it is no longer a novelty, and the writers are not thinking about it, the last year's date is often written until the new date, in turn, becomes a habit. Brides rarely make a mistake in writing their new name in the first few days after their marriage, but they often do so afterwards, until once more the new habit has been fixed. Because by repetition actions may become almost automatic or reflex, it is important not to develop bad habits. It is much harder to break a bad habit than not to acquire it. A saying of the great Leonardo is very true of the particular reflexes which are the basis of habit, " It is easier to resist at the beginning than the end."

Reflexes can be controlled by the higher centres. Many of the bodily functions in a baby are reflex, but as the child grows older control is gained. The centres for some of these actions are actually in the grey matter of the spinal cord, and control of these and others is developed in the higher parts of the central nervous system. Many acts of heroism and of sacrifice involve inhibition of natural reflexes—such as the rescue of someone from a blazing building where the natural reflex would make a person rush out of the building. Unfortunately, ugly things too are sometimes done because of lack of this power of control: a mob will behave as no single person would dream of acting.

The other function of the spinal cord is to carry impulses between the different levels of the cord and between the cord and the higher parts of the brain. Sensations from the skin (which tell us the feel of things), and from the muscles of the trunk and limbs (which are necessary for skilled movements), are carried up through a series of synaptic junctions to the cortex of the brain. From another part of the cortex, impulses are sent down the cord which produce and control movements of the muscles. We see therefore that the spinal cord is a very important structure, acting as a centre for very many reflex actions and as a conductor for messages to and from a large part of the body and the central nervous system.

The Brain (*Fig.* 8).

The greater part of the human brain consists of the two cerebral hemispheres, each with its outer layers or cortex, associated with the intellectual processes of memory, reasoning, and so on. Almost hidden by them is the small brain or cerebellum, which helps the body to maintain its balance and poise. Joining the brain to the spinal cord is a tapering portion known as the *medulla oblongata.*

This latter portion contains important centres which control functions necessary for life: breathing, the circulation of the blood, swallowing and a great many other essential activities. These are largely reflex in their action. Connected with the brain are twelve pairs of nerves, called the *cerebral*, in contradistinction to the *spinal* nerves. The first pair are the *olfactory* nerves; they are the oldest part of the brain and in most fishes they form the largest part of the brain. As their name suggests they are connected with the sense of smell. The second are the *optic* nerves, which carry

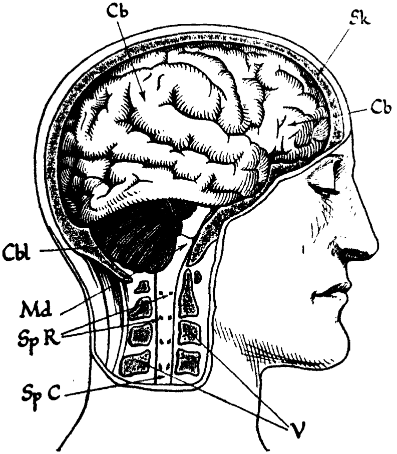

Fig. 8: Section through skull and vertebral column showing brain and spinal-cord.
Cb = cerebrum (cerebral hemispheres)
Cbl = cerebellum
Md = medulla oblongata
Sk = skull-bone
SpC = spinal-cord
SpR = spinal roots
V = vertebræ

the impulses from the eye which give rise to sensations of sight. The eighth pair are associated with hearing and also with balance. Taste sensations come in by the ninth. The tenth pair, called the *vagi* (vagus, the wandering nerve), spread very widely over the body, carrying messages to and from the brain and many organs, such as the heart, lungs and the digestive organs. Most of the other pairs carry mainly messages from the brain which control movements. Three pairs—the third, fourth and sixth—control the movements of the eye; the seventh pair, the muscles of the face (and so are called the *facial* nerves); and the twelfth the muscles of the mouth and throat. The fifth and ninth carry messages both ways to and from the face and throat and mouth.

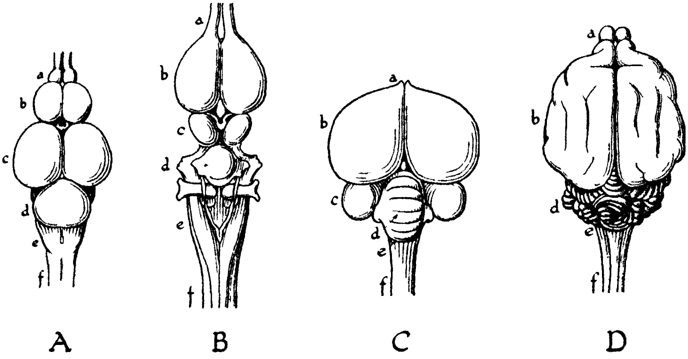

Fig. 9 : Dorsal view of brains

A = Perch
B = Frog
C = Pigeon
D = Cat

a = olfactory lobes
b = cerebral hemispheres
c = optic lobes
d = cerebellum
e = medulla
f = spinal cord

That the cerebral hemispheres are the parts of the brain which control the higher intellectual and emotional functions is a comparatively modern idea. In the Bible, for instance, the word brain is never used, and emotions are often associated with various organs, most often the heart. Such phrases as ‘ bowels of compassion,’ ‘ try my reins and my heart,’ ‘ a froward heart,’ ‘ the heart of the wise teacheth his mouth,’ ‘ a merry heart doeth good like a medicine,’ ‘ the words of a tale-bearer . . . go down into the innermost parts of the belly,’ show that emotions were associated with many different organs, but never with the brain. Aristotle thought the brain was a wet sponge. But gradually evidence of many kinds accumulated suggesting this connection.

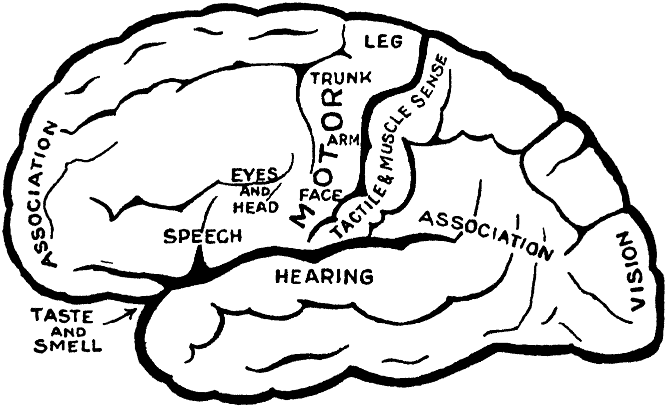

Fig. 10 : Diagram showing localisation of function in the cortex of the cerebral hemisphere.

First, there is the evidence of its development and structure. The cerebral hemispheres become relatively larger as the intellectual powers of animals increase (*Fig.* 9). The monkey has a much greater cerebrum than the rabbit, man a much greater one than the most intelligent of the monkeys or of the higher apes. Then certain parts of the brain are associated with special functions as shown in the diagram of the brain (*Fig.* 10), and these functions disappear if the parts of the brain associated with them are destroyed by accident or disease. This relationship is very close indeed. In the area marked *motor* there are not only parts that will cause big movements such as bending or stretching of the body, but there are areas that control the bending or straightening of the thumb or of a finger. The greater the skill and the variety of movements of a part the greater its representation in the brain. The hand has a much bigger part associated with its movements than the whole of the trunk muscles, and the part controlling the muscles of the throat used in speaking, is relatively large. When we consider what an advantage the power of speech gives us over all other animals, it is not surprising that it has considerable representation in the brain.

The relation between the cerebrum and the body is a crossed one. The right hand is controlled by the left side of the brain, and because speech and hand movements are evidently closely related there is in right-handed people a speech centre on the left side of the brain. Left-handed people have theirs on the right side of the brain, and sometimes training left-handed people to be right-handed makes them stammer. If it does it is probably wise to leave off the attempt. But because tools and implements are made for right-handed people and it is therefore more convenient to be right-handed, it is worth trying.

It is, apparently, not the weight of the brain so much as the extent of its surface that gives quality and capacity. To increase surface the human brain is folded or *convoluted.* In this way the surface can be enormously increased without unduly increasing the bulk. A kilt has much more material than a plain skirt, though this is not obvious when it is hanging straight down.

Learning seems to depend upon making connections between different parts of the brain by developing what are known as association-tracts. A person learning to read has to connect the look of the printed word with the sound of the spoken word and with the object for which the word stands. Thus the word *mouse* would not mean anything to a person who had never seen or heard of one, but to most people the word calls up a number of associations—what the *word* looks and sounds like: what the animal itself looks like with its long tail, its whiskers and its beady eyes. It brings up other impressions too: the noise it makes behind the wainscot, the smell it leaves, and even perhaps its taste—to those living in certain parts of England where fried mouse is still apparently given as a cure for whooping cough. The more quickly tracts can be made the more quickly learning can be accomplished.

Professor Pavlov, a great Russian physiologist, has carried out some interesting experiments which show how easily associations of the queerest kinds can be developed in the brain. Normally when an animal takes food into its mouth the fluids which will help to digest it are at once poured out. Even seeing the food will cause a secretion if the animal is hungry or likes the food. A hungry dog simply pours out saliva when it is shown a succulent bone (as a hungry baby may when it sees its bottle). But suppose before the dog is fed a bell is rung or a bottle of camphor opened near it, then in a very short time he has 'associated' feeding with the ringing of the bell or the smell of camphor, and then even without the food either of these alone will cause this outpouring of saliva.

Using the experiment the other way round, information can be gained about an animal's powers of appreciation of different stimuli. If when a tuning-fork of a certain pitch is sounded the animal is always fed, while with one of another pitch he never is, he learns to discriminate between them. The one if it is sounded will cause a secretion, the other, none. A dog in this way is found to have a keener ear for pitch than most humans. He cannot, however, detect colour or shape nearly as well. If a circular disc is associated with feeding and an oval one with not feeding, all is well so long as there is a decided difference between the two. If, however, the oval is a very short one, getting rather near to a circle and the dog is asked to decide between them, he gets terribly worried and upset, and the oval has to be lengthened to make him quite happy again. Very likely something of the same kind happens to human beings who are asked to do things that are too difficult intellectually or who are finding it difficult to decide between two lines of action.

The human brain has an extraordinary capacity for laying down associations, and this is not to be wondered at when we understand how many cells there are in its cortex. (In the cerebrum the cells are outside and the white matter or fibres inside: the reverse of the arrangement in the spinal cord). Sir Arthur Keith has calculated that in the brain of an average man there are enough cells to give two to every person living on the earth; or, putting it in another way, that a postage stamp on the cortex would cover nearly as many cells as there are people in inner London (about 5,000,000).

A nerve-cell in the brain, once destroyed, cannot grow again; but, as apparently we only develop a small fraction of the cells, we need not worry over this unduly, but think how much we can go on learning by developing some more of our cells. Perhaps this will gradually happen so that we can look forward to future generations becoming very much more intelligent than we are. Our very wonderful geniuses may be those who are making use of a greater number of cells and associating them in greater harmony.

All our lives we are of course learning to a certain extent: learning the way in a new district, getting to know fresh people and having all kinds of different experiences. But it is a good thing never to let the brain get out of the habit of doing a certain amount of what may be called intellectual work, so as to keep it always in the way of developing new association-tracts. This is perhaps especially necessary on leaving school when it may not be easy to keep up the habit without the familiar discipline. The intellectual qualities, just like the muscles, can get rusty and stiff if they are not used; but the brain has this great advantage over the muscles, that it can go on learning and making new associations long after the muscles have got old and tired. The great thing is to keep up the habit of learning.

CHAPTER VII

SPECIAL SENSES

LIVING beings have remarkable powers of adaptation. They can live in the tropics or in the arctic zones, in country or town, in dry or in wet climates, and indeed under all sorts of varying conditions; and they can protect themselves against sudden emergencies. To do all this, the body must be kept accurately informed of changes in its environment. This absolutely necessary information concerning the outside world is gained by means of the organs of special sense. They are: the eyes for vision; the ears for hearing and balance; the nose and mouth for smell and taste; and the skin for touch, temperature and pain. Without them we could not get on at all (in fact, we should be 'out of our senses'); but if only one sense, such as sight, is absent, it is possible very largely to compensate for this by an intensive training of the others. The senses have different degrees of importance at different ages. In the very young, sight is poorly developed and learning mostly depends upon hearing: later on this is reversed, and most of our information comes to us through the eyes. Blind children, as is well known, can become very intelligent and are comparatively easy to teach; but it is much more difficult in the case of completely deaf children who must be very specially trained right from the earliest age if they are to have a proper chance. Children who are deaf, in the sense of being 'hard of hearing,' though they must be carefully watched and given places where the teacher can be heard, can learn like the ordinary child, just as a child with defective sight can, if properly catered for.

For some reason deaf people are often treated with too little sympathy and consideration. It should be realised that, in being cut off from easy communication with their fellows, they suffer a great loss ; and, instead of being impatient with them, every effort should be made by speaking slowly and distinctly to give them the chance of entering into, and taking part in, the ordinary social life. Often the mistake is made of shouting when a slow and clear articulation would help them much more. When you are inclined to be impatient with the partially deaf, just stop and think for a few minutes how different your life would be and how isolated you would feel if you could not hear people talking.

The different kinds of sensory stimuli are picked up by special nerve-endings, but actual sensation is experienced only when the impulse gets to its own special region in the brain (see diagram of brain). Though the skin may be influenced by light, an impulse from the skin will not give rise to the sensation of light, because the impulses from it do not end in the eye-centres of the brain.

The Skin

When we take something in the hand and feel it or put it against the cheek, we get quite a lot of information about it. We know whether it is soft or hard, or prickly, or hot or cold and whether it is pleasant to the hand or painful. All this is learnt because the skin has certain sensory nerve-endings, by means of which it is possible to appreciate the sensations of heat, cold, touch and pain. There is a very general impression that these can be felt every-where on the skin quite equally, but closer examination shows that this is not so. If we try the effect of putting the point of a pencil, or a knitting needle, very lightly on to the skin of the front surface of the wrist, we shall find that in certain small areas there will be an intense feeling of cold: these areas are called *cold-spots*. If a cold-spot is marked with a dot of ink, or with a pencil it will be found always to give rise to this sensation when touched or stimulated in any way (not necessarily by cold). Similar spots can very easily be found on the skin of the cheek below the eye. By testing with a warm knitting needle or a pointed metal cylinder which can be filled with hot water *heat-spots* can be similarly shown. Heat-spots are not nearly so numerous or so easily stimulated as the cold, and so a bath of tepid water feels cold. Heat is specially well felt at the elbow; that is why a mother often tries the temperature of her baby's bath with her elbow.

If the skin is explored by pressing on it with the point of a pin or needle, *pain-spots* can be distinguished; and by pressing on it with the point of a fairly stiff bristle mounted on to a holder, *touch-spots* can be localised. Another power of the skin is discrimination of touch. A pair of compass dividers can be felt as two points when only about one millimetre apart on the tip of the finger or the lips, but on the shoulder or flank they have to be much further apart before they can be distinguished as two. In these regions the distance is so great that it seems impossible that the tested individual cannot really feel the two separated points. In making these tests the two legs of the dividers must be put down sometimes singly and sometimes double, and when double with an even pressure, otherwise the difference in pressure between the two gives information that two different points are being stimulated.

These observations show that even in the skin, where it is not obviously the case, special sensations are associated with specialised nerve-endings (*Fig.* 25, p. 163). Actual structures corresponding to these are not easily seen, though in the fingers there are some very characteristic nerve-endings called touch-corpuscles. The sensory endings are mostly in the deeper true skin, the dermis. The stimuli fall on the outer surface, the epidermis, but unless they are passed on to the deeper layers they do not give rise to sensation. A needle can be put into the upper part of the skin of the palm of the hand or of the sole of the foot without hurting.

A remarkable property of the skin is adaptation. The body gets so used to clothes, for instance, that they do not as a rule worry the wearer by continually giving rise to sensations of touch, though at first a new or clean garment may cause quite a lot of sensation. A dental plate in the mouth may at first cause quite acute, almost unbearable, pain. The bridge of a pair of spectacles may, at first, be almost intolerably uncomfortable on the nose, but when adaptation has occurred it may be noticed so little that the glasses can be hunted for when they are actually being worn. A good example of adaptation can be shown by putting one hand into hot and the other into cold water and afterwards putting both into a bowl of tepid water, when to the cooled hand it will feel warm and to the warmed one cool. Similarly the parts of the skin used to exposure do not suffer from cold to the extent of an area of the skin not usually exposed. It is wise not to be too reckless in exposing parts of the body which are usually covered, though excessive covering certainly prevents the skin from carrying out its proper functions. The skin has other important functions to carry out besides giving information as to the body's surroundings and these will be considered later.

CHAPTER VIII

SMELL AND TASTE

IT is convenient to consider these two sensations together as people do not usually discriminate very clearly between them. There are actually only four tastes: bitter and sweet, and acid (or sour) and salt. There are specialised nerve-endings in the tongue which give rise to these sensations. Those that are very well-developed are called taste-buds. They are found on some of the projections or *papillæ* which give the tongue its characteristic roughened appearance. The back of the tongue is most sensitive to bitter, the tip to sweet, and the sides to sour tastes; while salt is tasted pretty equally all over. A crystal of Epsom salt at the side will taste salt; at the front, sweet; and at the back, bitter. So, though sensations seem to be as general in the tongue as in the skin, it is seen that special sensations are taken up by special nerve-endings. Before substances can be tasted they must be in solution.

All the other so-called tastes and flavours are in reality smells. Smell is the most primitive of all the senses; and in some animals, such as deep-sea fish living where it is practically dark, it is almost the only one. In man it is clearly not so important as in other animals. This is not surprising when we realise that our special smell-apparatus has an area of only a quarter of a square inch, against ten square inches in the dog and ten square feet in the shark. Also, as against our two smell-areas, the South African ardvark (an animal that hunts at night for ants) possesses ten. Animals that hunt by smell nearly always have more smell-areas than those which hunt by sight. In many backboneless animals, such as ants and bees, this sense is important in helping them to find their way home and to recognise their friends and enemies.

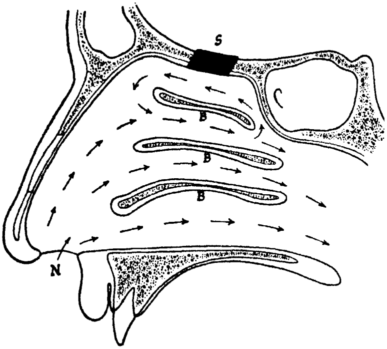

Fig. 11 : Arrows show direction of movement of inspired air.
B = scroll-like bones
N = nostril
S = smell area

In man, the organ of smell is on the uppermost fold of the bones of the nasal passages on the partition between the chambers (*Fig.*11). The sensation is only roused when air is actually moved over these patches—hence the habit of sniffing when it is desired to detect a smell. If the passage gets blocked (as it sometimes does with a cold) by the thickening of the membrane on the scroll-like bones of the nose, and air cannot be drawn in, then the sense of smell is lost—though it is generally interpreted as a loss of taste. Other animals certainly seem to learn a great deal more than we do by smell. But though this sense seems to be getting not only relatively but absolutely less in ourselves, it is still very delicate. It has been calculated that mercaptan, a rather unpleasant-smelling gas, can be detected when there is only 1 mgm. in 20,000,000 litres in air. Since there will only be about 1 c.c. of air in the nose at a time, it means that $\frac{1}{20,000,000,000}$ mgm. can be smelt! It would be a pity if the sense of smell went altogether, for though it is not perhaps a matter of regret that we do not usually recognise our friends by means of our noses, we should lose a great deal if we could not smell flowers and trees and earth and other good and pleasant things.

Perhaps, in ourselves, we under-rate its importance because in ordinary life sight and hearing are so predominant; or because, as some suggest, we fatigue its end-organs by over-stimulating them with strong odours such as tobacco. The sense of smell is certainly very easily fatigued, which is perhaps the reason that people can tolerate the terrible 'fugg' that is developed in a badly-ventilated room, the smell of which is almost intolerable to anyone coming in from the fresh air outside. Strong scents also produce fatigue of the nerve-endings very easily and those who make a habit of using scent or strong-smelling soaps should be warned that an amount of scent that they do not notice at all may be unpleasantly strong to others. On the other hand, delicate scents such as wild thyme do not seem to fatigue these endings at all.

Possibly the primitive nature of this sense is responsible for the extraordinarily vivid way in which a scent will sometimes call up memories.

CHAPTER IX

THE EAR

THE ear (*Fig.* 12) is a complicated structure with a very fine and wide range of sensation. As far as hearing is concerned, it is essentially an apparatus for taking up the vibrations of the air by which sound is produced, and transmitting these to some specialised nerve-endings from which impulses are passed on to the brain. The ear is made up of three parts: an outer, a middle and an inner; the nerve-endings being found in the last part. The outer ear is made up of the external leaf-life portion (which to many actually is the ear), and of a tube about an inch long, down which the sound-waves travel. At the bottom of this tube, and completely closing it, is a membrane, the tympanic membrane (or drum, as it is often called). This membrane plays the part of the telephone receiver, and vibrates when the sound waves of the air reach it. The passage, the external auditory meatus, leading to it, has in its walls cells which secrete a sticky, bitter, waxy substance which prevents insects from creeping into it. Sometimes the wax is secreted freely enough to block the passage and cause temporary deafness by preventing the moving air from getting to the tympanic membrane. If this happens great care must be taken not to attempt to clear out the wax by poking any hard instrument into the passage. The membrane is only about an inch down and it is easily possible to reach and injure it. If syringing out the ear becomes necessary this should be done gently and carefully or the drum may be burst.

Constant filling of the ear-passages with water whilst bathing is harmful: in swimming, it is wise, therefore, either to plug the ears with vaselined cotton wool beforehand, or, after coming out of the water, to turn the head so as to let out any water which has entered the ear-passages, and to dry them very carefully.

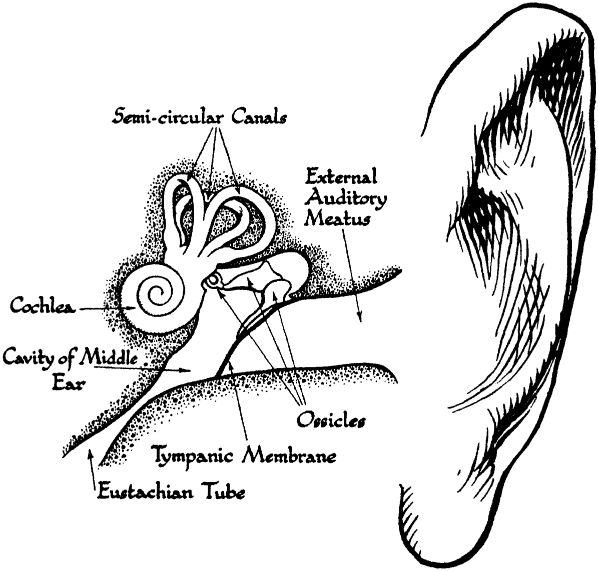

Fig. 12: The Ear.

On the other side of the drum is the middle ear which lies in a space hollowed out of the very hard temporal bone of the skull. Beyond this there is the cavity of the inner ear. In the side of the middle ear opposite to the tympanum are two windows, an oval and a round one, which are covered over with membranes. Stretching from the tympanum to the membrane covering the oval window, is a chain of three very tiny bones or ossicles: the hammer-bone is joined to the drum, and the saddle-bone joins the hammer-bone to the stirrup-bone, which fits against the oval membrane. When the membrane vibrates, this sets in sympathetic motion the chain of ossicles: the little stirrup-bone is pushed against the membrane of the oval window, and this in turn moves some fluid, called *perilymph,* in the internal ear. To get the best possible response from a very small membrane like the tympanum it is necessary to have the general pressure of the air equal on both sides. Ordinary air can get freely to its outer side, and so air must be able to get to its inner side. This is arranged for by a tube, the Eustachian tube, which opens from the middle ear into the throat. It is thought that it only opens during the act of swallowing; and certainly very often sound is heard when swallowing air, or when blowing down the nose with mouth and nostrils closed (which raises the pressure in the throat). If this tube is blocked, as it sometimes is by the inflammation of the throat during a cold or, more permanently, by enlargement of the adenoids, the air cannot pass freely into the middle ear. Some of the air is absorbed and so the pressure of the air in the middle ear gets less and the tympanic membrane is sucked in and cannot move freely and deafness results. People going up very quickly in aeroplanes to heights where the atmospheric pressure is low often suffer temporary deafness, because in this case the pressure inside the middle ear is greater than outside, and so the tympanum is bulged out. Going into a tunnel in an express train gives inequality of pressure and consequent deafness. These temporary deafnesses can be improved by swallowing.

In the wall of this second chamber, in the side towards the brain, there are cellular cavities which make the partition between this chamber and the membranes of the brain a very thin one, so that there is danger of an infection in the middle ear passing from it to the brain. Any ache or pain in the ear should be medically attended to at once; in this way trouble which otherwise might be serious is prevented. A child may appear stupid simply because he has not heard, and teachers and others in charge of children should always satisfy themselves that a child who finds difficulty in speaking or learning is not suffering from some degree of deafness. Very often this can be relieved if taken in time.

The third, or internal, part of the ear contains the specialised sensory nerve-endings. It is such an extraordinary shape that it is called the *labyrinth.* The nerve-fibres end in an inner membranous labyrinth (containing a fluid called *endolymph*), outside which is a bony labyrinth separated from the membranous one by the fluid previously referred to, the *perilymph.*

The part of the labyrinth connected with hearing is shaped like a snail's shell and is called the *cochlea,* here the nerve-fibres end in connection with stretched fibres, which vibrate as the strings of a piano will if, with the lid open, a note is sung into it. When the stapes pushes against the oval window, its movements are carried by movement of the perilymph and endolymph to these fibres and when they vibrate they stimulate the nerve-endings connected with them, and the nerves carry the impulses to the auditory part of the brain, which then really *hears* the sound.

Our range of hearing is very great—about eleven octaves, of which about eight are used to music. The bat's squeak is at the upper limit of human hearing (about 56,000 vibrations a second), and many people cannot hear this sound. Dogs can hear notes of much higher pitch; tested by a Galton's whistle, they will start when the whistle, set for a very high note, is blown, though we can hear nothing. The low organ-pipe gives a note which is at the lower limit (thirty-two vibrations a second), and that causes a smothering kind of feeling rather than a sensation of sound. Besides pitch, we can appreciate intensity or loudness and quality. By quality we recognise the different tones of our friends' voices, and of the various kinds of musical instruments. All these different sounds, many thousand of them, can be appreciated by the nerve-endings in this tiny organ, the cochlea.

The rest of the labyrinth, which consists of two chambers called the *saccule* and *utricle* and of three *semicircular canals* set in the three planes of space, enables us to appreciate movement of the head or body and our position in space. A person lying on a turn-table, if the table be swung round, is able to judge pretty accurately the angle through which he has been moved, by the variations of pressure of the endolymph inside these canals. In making such judgments, the canals of the two ears work together. The messages from these parts of the ear go up to the cerebellum.

If we turn ourselves very quickly, so as to set the fluid in the canals moving, and then stop suddenly, giddiness is felt, because the eyes and ears are telling different tales—the ears when the fluid is still in motion, give the impression of motion and the eyes see there is no motion. If, before spinning round, the head be lowered to touch the top of a walking-stick, the confusion is still worse; and, when the spinning is stopped, the giddiness caused is so great that the person is almost certain to fall down directly he stops moving.

In the endolymph of the semicircular canals there are sometimes found little lumps of calcium carbonate, called *otoliths*, which exaggerate the movements of the fluid, and so help the body to keep its balance and to know its position in space. Otoliths are found in other animals which have to balance themselves. Shrimps actually put particles of sand in their balancing organs to act like otoliths. If iron filings are put in the sand, the shrimp may put them in its balancing organs and then, if a magnet is held over it, the filings press upwards and the shrimp turns over at once and swims upside down!

Many animals can move the external part of the ear, and this enables them to judge much more accurately the direction of sound. If we watch an animal pricking its ears, we can see that the ears are being turned in such a way that an imaginary line joining them would point in the direction from which the sound is coming. We cannot move our ears, and so have to move our heads when we are trying to find the direction from which a sound is coming. Without doing this we should judge very badly, as can be shown by a very simple experiment. Close the eyes, and then get someone to make a sound fairly close to the head, by rattling some keys or clicking two pennies together. If this is done in the middle line of the head from the chin to the nape of the neck, it is impossible to be sure whether the sound is made in front of or behind the head. The further out of this middle line the sound is made, the more accurately it will be located.

Every care should be taken of the ears and of the sense of hearing. A child who is completely deaf loses the easiest way of learning. For centuries people who could not hear were dumb also, as there was no way of learning words, so they could not speak or read, and remained undeveloped. Now such children are taught the value of words, as the names of objects and as the way of expressing ideas, and so their mental powers can be properly developed. But it is a great handicap to children even to be ‘ hard of hearing ’ and so special efforts should be made to see that they do hear properly. This holds equally for adults who are deaf and who may in that way be somewhat cut off from their companions.

CHAPTER X

THE EYE

THE eye is the organ of sight. It consists, on the one hand, of the specialised nerve-endings of the optic nerve in the retina, sensitive to the stimuli of light and colour, which they receive and pass on to the brain, and on the other, of a series of curved surfaces concerned in bringing the image of external objects on to the retina.

The eyeball is almost a sphere, of about one inch in diameter. The apparent differences in the sizes of eyes is illusory, being due to the arrangement of the eyelids and the amount of the white of the eye which is showing. All eyeballs are practically identical in size. The eye in general is protected from injury by being placed in a deep socket in the skull, and by being fitted with the eyelids. The upper eyelid only is movable, and it shuts down if anything dangerous is seen approaching the eye. The eyelids also protect the eye against the entry of dust and particles when the eyes are closed. Connected with the lashes there are glands which pour out an oily secretion which prevents both the eyelids and the lashes from sticking together. When one of these glands is blocked, as sometimes happens, it produces the minor but painful condition known as a stye. The eye is kept moist by a constant secretion from the lachrymal or tear gland, which lies under the upper edge of the bone forming the eye-socket at its outer side. The secretion is generally small in amount—only just enough to keep the eye moist—and is drained away through two small openings (one at the inner end of each eyelid) which open into the cavity of the nose. When this secretion is formed more quickly than it can be drained away there is an overflow known as tears.

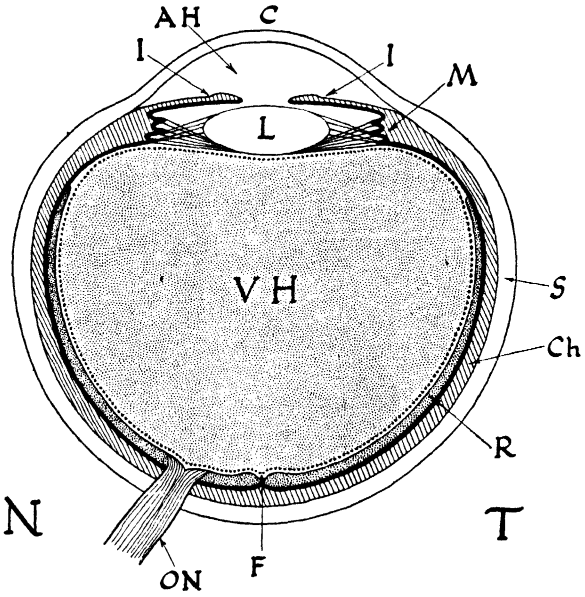

Fig. 13: Section across the eye-ball

N = nasal side
T = temporal side
AH = aqueous humour
C = cornea
Ch = choroid coat
F = fovea
I = iris
L = lens
M = muscle for accommodation
ON = optic nerve
R = retina
S = sclerotic
VH = vitreous humour

The eye is made up of three coats (*Fig.* 13), the outer one is protective and its opaque part forms the white of the eye the *sclerotic*, but in front where it becomes the *cornea* it is transparent to allow the rays of light to pass through. Within this comes the second or nutritive coat, the *choroid*, very richly supplied with blood vessels and with a considerable amount of unstriped muscle in some of its parts. This coat is not complete in front, the gap forming the pupil. The pupil can be made larger or smaller by the action of the muscles of the *iris*, the coloured portion of this coat, which acts like the stop in a camera.

The innermost of the three coats is the *retina*. This is the part which is sensitive to light and it fits closely to the others (rather as a cup would do), with its rim about two-thirds of the way up the eye-ball. It contains on its outer side some specialised cells, the rods and cones that are so stimulated when light is focussed on to them that they pass on messages to other nerve-cells in the retina. The axons of the last of these form the bundle of fibres known as the optic nerve, which finally carries the impulses to the occipital or hinder portion of the brain where visual sensations are appreciated. Since there are no rods and cones at the place where the optic nerve leaves the eye, at this point there is no possibility of vision. Paradoxically therefore the place where the impulses of sight are collected to pass to the brain, forms what is known as the blind spot.

Close behind the iris is the lens which, together with the cornea, focusses the rays coming from an object and makes a clear picture of it on the retina, the region of most distinct vision in the retina is called the fovea. In a camera, focussing is effected by altering the distance between the lens and the screen, but in the eye it is done by altering the curvature of the lens. The lens is supported by a circular sheet, the suspensory ligament, which stretches from the edge of the lens to some projections of the middle coat. When the eye is looking at distant objects these projections are far enough away to keep the suspensory ligament stretched—which then by pulling on the lens keeps it flattened. When near objects have to be looked at, the projecting processes are pulled forward by the contractions of muscles in the middle coat of the eye, and the suspensory ligament is slackened. The lens is elastic, and so, on being released from the flattening pull, it becomes more curved. This change is known as *accommodation* and involves considerable muscular activity. The effort can sometimes be felt when quickly looking from distant to near objects. The nearer the object the greater the amount of accommodation necessary to focus it properly, and so the greater and more fatiguing the effort. The muscles have to remain contracted all the time the eye is accommodated; for this reason close work should not be continued too long, and the object to be looked at never brought closer than 10 inches. This is particularly important for children. The lens in a child's eye is very elastic, and objects *can* be focussed when only about 4 inches away. This makes the lens alter its curvature more than it should, and if persisted in the eye becomes permanently too curved and the child becomes short-sighted or myopic.

No one, and more particularly no young person, should read or do fine work in a bad light, or hold the object too near the eyes. Young children should, indeed, never be allowed to do fine work at all, neither should they be given small print to read. In reading small print it is very likely that a child will mistake what is really a difficulty in understanding for a difficulty in seeing. In an attempt to see better it will bring the objects too close, and so produce the harm that comes from excessive accommodation.

Occupying the space between the cornea and the lens, is a fluid called the *aqueous humour ;* and between the lens and the cup-shaped retina, a jelly-like mass, the *vitreous humour.* The eyeball is moved by six muscles attached to its outer coat—the sclerotic—and these give it a very great range of movement. Normally the muscles work in a perfectly co-ordinated manner ; but sometimes they do not and a squint is produced. This condition, if properly treated, can generally be cured, and is always much improved by treatment.

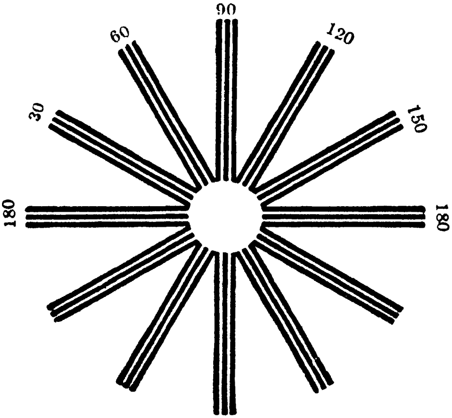

Fig. 14 : Astigmatic Chart (*Howell*).

The eye is not a perfect optical mechanism : sometimes it is not spherical, being more curved in one direction than in another. In other words, it is egg-shaped rather than spherical. This condition is known as astigmatism, and produces a blurring of an image, since if the eye is focussed for one set of lines it will be out of focus for lines at right angles to these (*Fig.* 14).

Sometimes a child is born with an eyeball which is too long from back to front. This condition may also be produced by incorrect use of the eye when it is young and elastic. Only rays from near objects can then be focussed: distant objects will look blurred. This is *myopia* or short sight, and can be compensated for by spectacles with concave lenses. Sometimes the eyeball is too short and can focus rays from distant objects but cannot by even the greatest effort of accommodation become thick enough to bring on to the retina rays from near objects. This is *hypermetropia* or long sight, and is compensated for by convex lenses. As people pass the age of forty a condition, known as *presbyopia* or old-age sight comes on, in which the elasticity of the lens being lessened the eyes cannot be focussed satisfactorily for near objects, and convex lenses have to be, or should be, used for reading. People who have had very good sight often do not realise the necessity for having glasses, but they should be warned of the dangers of neglect and of the necessity for consulting an oculist if they find themselves holding a book or paper from which they are reading further and further away, and also if headaches are becoming common.

Like most other lenses, the eye-lens is truest in the centre; and so, when it is accommodated to look at near objects, the iris contracts to cut down the pupil and expose only the central part of the lens. In the dark, or when looking at distant objects, the pupil is dilated to let in as much light as possible. This shrinking of the pupil can be very well seen by covering the eye with the hand for a minute, so as to let it dilate in the dark, and then looking at a brightly lighted mirror. The change is shown very well, too, in a cat's eye. At night the pupil is so large that there is hardly any coloured part showing: in the day it may be reduced to a mere slit.

This protecting of the eye against too strong light is very important. It is partly secured by contracting the pupil, and in a very bright light is helped by the closing down of the lid ; but though this is enough for a short exposure it is not enough for prolonged exposure. Babies should never be left in their carriages so that they face the light. If the carriage or other vehicle has to be left in this position some sort of awning or shade should be used.

On the other hand any kind of work should be done in a good light and not in a flickering light, such as firelight, which almost certainly necessitates holding the book or work too close to the eyes. To prevent a shadow being cast the illumination should come from the side and above. For writing and work involving the hand (which is usually the right hand) the light should come from the left side.

Another quality of objects that is recognised through the eye is colour. The normal eye can appreciate all the seven colours of the spectrum of which white light is made up. But some people are colour-blind, and cannot distinguish between colours which are very different to normal eyes. The most common form is red-green colour blindness, which means the sufferers cannot distinguish between these two colours. The defect may not be detected for years, and this fact makes one realise how individual each person's experience is. It is difficult to imagine what people do see who cannot distinguish cherries on a tree from the leaves of the tree except by their shape. The story goes that colour blindness was first discovered about a hundred years ago when a man in a village shop wanting some grey stockings pointed to some scarlet ones, saying he would prefer these to the ones he had been shown. Since those days this defect has been much investigated by means of special lanterns and coloured plates. Some individuals are yellow-and-blue blind, and others cannot see colour at all but only different intensities of light.

Persons wishing to enter naval, military, or railway services are tested for colour-vision, since red and green are colours used in signalling, and confusion between them would mean disaster. In view of the widely-extended use to-day of such signals on the roads it will become more and more important that everyone's colour-vision should be tested; and those who have defects should be aware of them and so avoid running risks of motoring accidents.

By training, colour-blind persons can be made to distinguish some differences, probably of intensity, between the difficult colours when they have chances of comparing them but still do not know which is red and which is green if the colours are shown to them separately and singly.

We can be very easily deceived by our eyes, and a large number of amusing examples of optical illusions are known. The impression of solidity is due to the fact that a slightly different picture of an object is seen by each eye. The two pictures looked at in the stereoscope are taken from the viewpoints of the two eyes and when superimposed they give the impression of a picture in three dimensions, though looked at separately each is apparently an ordinary picture in two dimensions. Our vision is binocular as our hearing is binaural.

CHAPTER XI

THE BLOOD

THE blood is the great distributing agent of the body. It carries to every cell all the materials—food, water, oxygen and so on—that the cell needs for its well-being and its work; and it carries away from the cell substances it may have manufactured that are needed by other parts of the body, as well as any waste materials that have collected during its activity. In a grown-up person of average size there are about five quarts of blood; and as it is pumped round and round by the heart this comparatively small quantity is enough.

If we look at a drop of blood under the microscope it is seen to be made up of a clear, pale-yellow fluid, called the plasma, and floating in this an immense number of small, solid structures, called corpuscles. There are two kinds of corpuscles, red and white, and the red are much the more numerous (*Fig.* 15). In a drop about the size of a large pin-head (accurately, a cubic millimetre of blood) there are 5,000,000 red and only about 10,000 white corpuscles. The red cells are tiny biconcave discs, pale-yellow if seen singly, but red if in piles or in large quantities. The characteristic colour of blood is due to their presence. They are so small that if they were put side by side on their flat sides, more than 3,000 of them could go into the length of one inch; and if they were placed on their edges, then it would take about 12,000 of them to reach across the inch. They are red because they carry an iron-containing substance, called hæmoglobin. This is a very important substance because it has the useful capacity of combining with oxygen when there is plenty about, and of giving it up in places where it

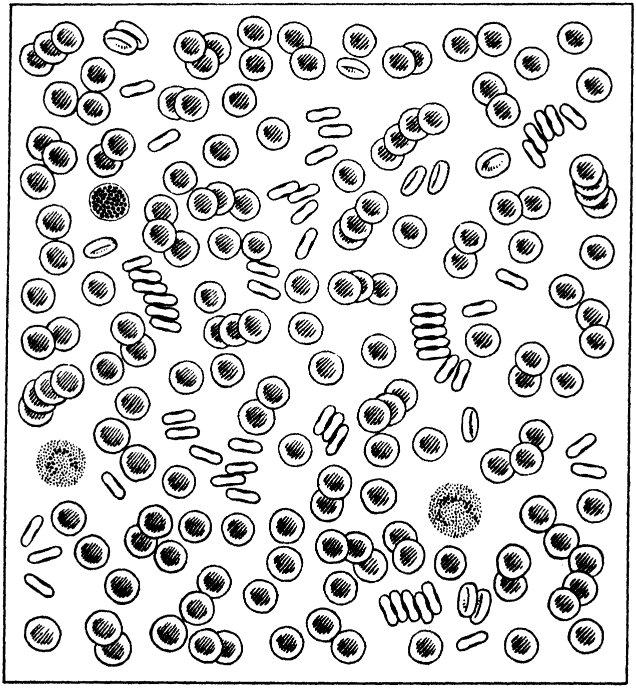

Fig. 15 : A drop of blood seen under the microscope, showing three white corpuscles and many red corpuscles.

is scarce. Since we must have oxygen or die, the red corpuscles are absolutely essential for life. In the lung capillaries the hæmoglobin takes up oxygen from the air in the lung-pockets, and then this blood, charged with oxygen, is carried to the heart and from there sent out all over the body—where the red blood corpuscles give up their oxygen because the cells always seem, like Oliver Twist, ‘to want more.’ As a rule they only give up a small part of their oxygen, about one-quarter ; but they can give up more if the cells are wanting more. Muscles, when they are working hard, want a great deal of oxygen ; but when they are working they get more blood, and so only have to take up about the same amount of oxygen from each drop of blood. If, for example, the blood coming to the muscles were doubled in amount that would mean that they would get twice as much oxygen, even if they only took up the usual quotient. But, if that was not enough, and they still wanted more they could get perhaps three times as much oxygen as usual from each drop and so get six times the amount of oxygen that they took when they were resting.

That is the work of the red blood-corpuscles : to collect oxygen in the lungs and give it up in the tissues. Each corpuscle, it is thought, lives only about thirty days. At the end of that time it is worn-out and gets broken up in the liver and perhaps in the spleen. Because the worn-out ones are broken up new ones must be made all the time, and this replacement takes place in a queer place—the marrow of the bones. As it is the iron in the hæmoglobin that makes it able to take up the oxygen, iron is rather precious ; and when the red corpuscles are broken down only the non-iron-containing part is got rid of (it gives the colour to the bile), while the iron is carefully kept in the liver to be used again in making fresh hæmoglobin for the new corpuscles. But in spite of this care to preserve the iron, some of it does get wasted, so to make up for this loss there must always be in the food that is taken some which contains iron.

People who have not enough hæmoglobin are said to be anæmic, and are sometimes given iron-tonics.

The best thing, of course, is to have foods that have enough iron—you will learn in later chapters that green vegetables and egg yolk are good sources of iron. But some of the vitamins must also be present or the iron cannot be built up into the hæmoglobin.

Some amusing calculations have been made to show how many red blood corpuscles are made in the body. If, for example, all the cells were laid out flat, one deep, edge to edge, they would form a pavement a foot wide and about six miles long—or a red tape half an inch wide and one hundred and forty miles long! It seems almost impossible, of course, but arithmetic will prove that these figures are correct.

Hæmoglobin without oxygen is a bluish-purple colour, with oxygen it is bright red: this accounts for the difference in colour between arterial and venous blood. The more oxygen is taken into the lungs, the more arterialised the blood will become. That is why running or skipping or taking any other exercise until it is necessary to breathe very deeply, is so beneficial. Fresh air gets into the deepest parts of the lung, and so all the blood going through the lungs gets a full oxygen supply.

The white cells or leucocytes differ both in structure and in the work they do, from the red corpuscles. They are not homogeneous. They are real cells, and so each one has not only a cell-body in which there are lots of little granules, but also a nucleus. The leucocytes in human blood are mostly a little larger than the red corpuscles. The great work done by the leucocytes was finally proved by the great Russian scientist, Metchnikoff. It is said that he put rose-prickles into the transparent larvæ of star-fish, and discovered that these white cells crowded up and surrounded the prickles to protect the body! It seems a far cry from rose-prickles and star-fish to the understanding of the protection of human beings against microbes which are the carriers of deadly diseases, and yet that is exactly what came from these experiments. Metchnikoff give a wonderfully dramatic picture of the way in which protection is secured. If harmful bacteria get into the body through a scratch or cut in the skin, for example, information is in some way sent round, probably by means of chemical messengers and the leucocytes come hurrying up to the scene. They surround the invaders (*Fig.* 16), and a silent battle takes place in which each side is trying to kill the other by sending out poisonous secretions. The poisons sent out by the leucocytes probably come from the granules in their bodies. If the leucocytes are at first defeated—and those in the immediate neighbourhood of the enemy are often overcome—their places are taken by fresh cells which come up and close the gaps. Their dead bodies form part of the 'matter' or pus which is sometimes found in inflamed parts. When the

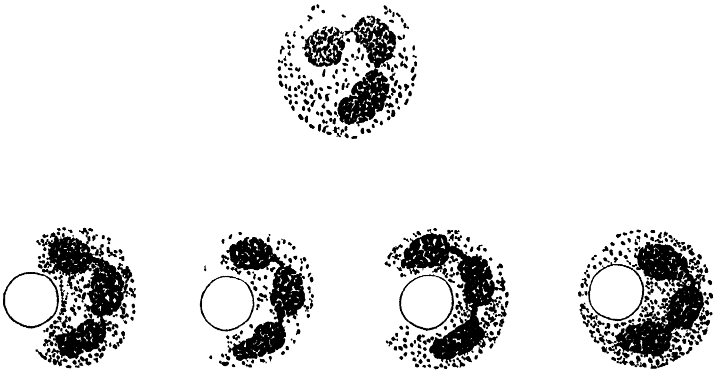

Fig 16: **Showing white corpuscle gradually surrounding an invader.**

leucocytes have won—and they usually do win in the end or people would not live so long or get over infections as well as they do—they advance and become cannibalistic and devour the bodies of the enemy, a single leucocyte accounting for quite a number. Having cleared up the situation they go back into the general circulation and digest their victims at leisure. Of course, things do not always go quite so well as that. Sometimes the bacteria get into the body and go on increasing. Then the battle is a much fiercer one, and in that battle perhaps millions of white cells die before the body finally gains the upper hand. The cleaner the skin the less chance there is that the enemy may be in the neighbourhood of a cut and so get in. As it is very difficult to be sure of complete cleanliness it is wise, in case of a cut, to use an antiseptic like iodine, which, by killing surface germs, helps to protect the body.

The leucocytes do not always eat their enemies. In addition to sending out poisons, they sometimes make *antitoxins* which neutralise the action of the *toxins* or poisons which the invaders are making. A person who has had a disease such as diphtheria, for example, makes such a lot of antitoxin that there is enough in quite a small quantity of his blood to protect another person against the disease. Nowadays a great many people's lives are saved by injecting into their bodies (when they are likely to run the risk of infection, or are in the early stages of the disease) antitoxin which has been obtained from an animal that has cured itself against infection by the same disease. Our soldiers in the war were successfully protected against typhoid by inoculation; and children can be protected in a similar manner by appropriate inoculations against the risk of smallpox and diphtheria. These are becoming very much less prevalent than they were, but if everyone were protected, the diseases would probably disappear altogether. There is a town in Canada where, as a result of inoculation against diphtheria, the disease *has* disappeared, and the hospital which was kept for these cases has actually been closed.

The blood of very healthy people protects them in another way, by making what are called *opsonins*, which act rather like a sauce! It is found that germs which have been treated with the fluid part of healthy blood are taken up much more readily by the leucocytes than those that have not been so treated. That is why the name opsonin, which comes from a Greek word meaning "I prepare the feast", was given to them by their discoverer, Sir Almroth Wright. So you see, the blood has many ways of protecting the body. People can assist the blood by being in the fresh air as much as possible; by sleeping with windows open—and sleeping enough; by taking exercise; by eating sensible food; and, also, by not being afraid!

As the blood carries oxygen as well as everything else that has to go to or from the cells and protects us against disease, it is a very precious possession and it will not do to lose too much of it. Since the blood is circulated round the body in a system of closed vessels there would be a real risk of losing all the blood if a hole were made in one of these vessels and nothing was done about it. Common experience teaches us that, if during a frost, ice has formed inside a water pipe, and by its expansion cracked the pipe, when the thaw comes water pours out. When a blood vessel is cut or torn the same sort of thing does not happen because blood, when it is shed, has the property of being able to form a clot, or to coagulate. If the hole is a small one, this clot blocks it up and stops the bleeding very quickly, the vessel-wall is then repaired and so no harm is done. If, however, there is extensive damage, the bleeding has to be stopped by bandaging or stopping the circulation in the damaged part to prevent the clot from being washed away as fast as it is formed. There are some people whose blood will not clot at all easily, and they may suffer seriously from a small cut which in normal people would be stopped bleeding in a minute or so. This is a curious condition which is passed on from one generation to another.

All this goes to show that the quality of being able to clot is an essential property of blood.

CHAPTER XII

CIRCULATION

THE circulation of the blood was discovered by William Harvey who was physician to Charles I. Harvey is often called the Father of English physiology because of the way in which he arrived at his discovery. He made careful observations and experiments extending over many years, before, in 1628, he published his famous book on the motion of the heart. This is a remarkable demonstration of the way in which experiment and theory should be linked together. The view about the movement of the blood that had been accepted for hundreds of years was that the blood was made directly from the food taken in and then was sent to the heart. There it became mixed with air and was sent out ; the two flows being quite distinct from one another. Harvey measured the size of the biggest chamber of the heart, the ventricle, and found that it would hold about four tablespoonfuls, and that this amount was pumped out of it at each heart-beat. Assuming that this happened seventy-two times a minute, then in one hour 8,640 tablespoonfuls of blood, weighing 540 lb., or more than three times the weight of an average man would have been pumped out. It followed from this, that in twenty-four hours a man would have to eat a quantity of food weighing seventy-two times as much as his own body : which is absurd !

Harvey also showed that in the heart, blood could only pass from the auricles to the ventricles, and from the ventricles to the big arteries leading from them ; and that flow in the opposite direction was

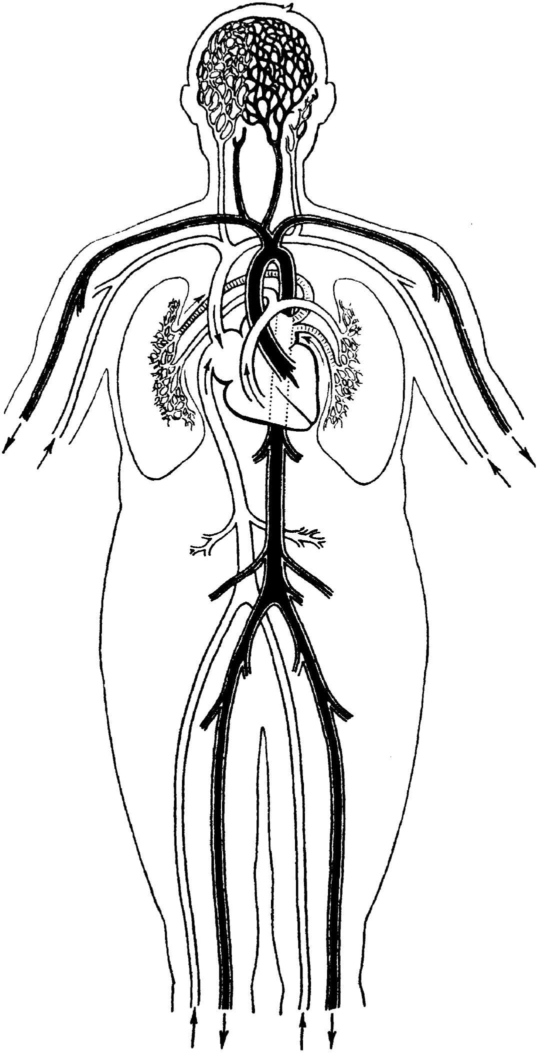

Fig. 17: Diagram showing Circulation of Blood. Vessels carrying venous blood are shown unshaded.

stopped by sets of valves between auricles and ventricles and ventricles and arteries. The valves in the veins would only allow blood to pass to the heart, not away from it ; and, finally, he showed that substances directly injected into one vessel could be found in blood-vessels all over the body.

A study of the diagram of the circulation (*Fig.* 17) will show its direction ; and, also, that in man there are two circulations. One is from the right to the left side of the heart through the lungs, where the blood takes up oxygen and gives up excess carbon dioxide. The other is from the left to the right side through the body, taking oxygenated blood to all the tissues, which receive oxygen and give up carbon dioxide, and also are supplied with, and give up, all other substances used, or made, by them.

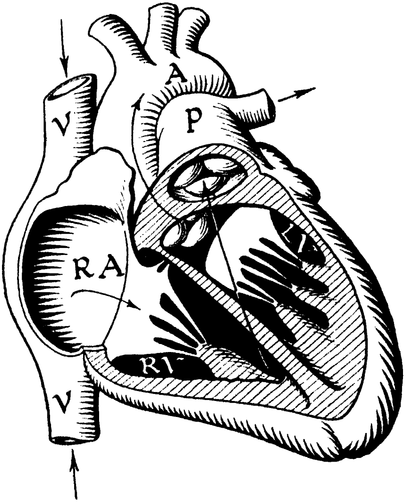

Fig. 18 : The Heart.

A = aorta
LV = left ventricle
P = pulmonary artery
RA = right auricle
RV = right ventricle
V = venæ cavæ (veins by which blood returns to the heart from the upper and lower parts of the body).

The heart is made up of cardiac muscle, and like any other muscle its function is to contract. This particular contraction is very important as it is the motive power of the circulation of the blood : if the heart stops, the circulation stops.

The heart has four chambers: two upper ones, called auricles, and two lower, called ventricles (*Fig.* 18). The right and left sides of the heart are quite separated from one another, but each auricle opens into the ventricle on the same side. Between the auricles and the ventricles are valves which—like lock gates—are open to traffic in one direction only. They are arranged so that blood can pass from auricle to ventricle; but, so long as they are working properly or are competent, it cannot pass from ventricle to auricle. The valves are triangular flaps from whose edges run little tendinous strings, attached at their other ends to the wall of the heart. These strings prevent the valves from being turned inside out like an umbrella in the wind when the blood is pressed against them. Where the big arteries leave the ventricles there are more valves: this time they are pocket- or cup-shaped, and allow blood to pass from ventricle to artery but not in the reverse direction. In this way the direction of the circulation is arranged.

The heart alternately works and rests. When it is beating at the rate of seventy-five beats a minute, the contraction of the auricle will last about one-tenth of a second and its rest for seven-tenths. The ventricle words harder, and its contraction which follows immediately after that of the auricle, lasts about three-tenths of a second. Its rest-pause lasts for about five-tenths of a second; so that even the hard-working ventricle only works for half of its life. When the heart beats more quickly, the resting-time is cut down.

It is no wonder that the heart has to rest for a good part of its time, for even in ordinary quiet life it has to do a very considerable amount of work. In a man weighing eleven stone, the heart does in an hour as much work as would raise his whole body up a flight of stairs about nineteen feet high, or in twenty-four hours enough work to take him up a hill 450 feet in height. If he is doing hard work, the muscles will need much more oxygen and, consequently, much more blood will have to be sent to them, and the heart will have to work much harder.

There is only a certain amount of blood in the body, and so if more oxygen is needed it can only be provided by sending the blood round more quickly. Circle-trains, for example, running just often enough to keep the stations cleared, would have to run twice as often if twice the number of people had to be transported. In the same way, the red blood-corpuscles, if they have to carry more oxygen, will have to go to the lungs more often; and, that means, the heart will have to pump the blood round more quickly.

In very strenuous exercise—such as rowing in a race—the muscle contractions drive the blood back so quickly to the heart, that it may have to be pumped round six times as fast as under ordinary conditions. For this kind of exercise, people have to go into training in order that the heart may gradually be adapted to the new demands laid upon it by having its cavities enlarged and its walls thickened.

The heart—like any other muscle—gets larger if it is exercised; in race-horses and greyhounds the heart is very much bigger in proportion to the size of the animal than in ordinary horses and dogs. The athlete, too, will have a larger and more muscular heart than the less active person to enable him to carry out the extra work that is demanded of him. But a person in good condition, even if the heart has not been specially developed by previous training, can respond in a very satisfactory way to a sudden call for extra work. If, however, this is pushed too far, the walls, not having been thickened by training to stand the pressure of the extra amount of blood that is being returned to the heart, will stretch in such a way as to leave them thinner and weaker : the heart is then said to be dilated. If the heart-muscle is already weak and flabby, dilatation will certainly be caused by any excessive activity and, possibly, even by exercise which normally would not be at all strenuous.

In some diseases (of which diphtheria and rheumatism are examples) poisons, produced in the body, attack and seriously weaken the cardiac muscle. People who have suffered from these illnesses have, therefore, to be very careful—and sometimes for quite a long time—not to put any strain on the heart. If they are careful the poison will gradually be washed out and the heart get quite right again. For this reason, even though it is very tiresome not to be allowed to play vigorous games or go for good walks when feeling quite recovered from such an illness, as long as the doctor says a patient must go slow he should do so.

The normal rate at which the heart beats and the blood is circulated, depends very largely upon the size of the animal, or more accurately speaking, upon the relation between the animal's surface-area and its size. The average pulse-rate in the adult male is between seventy and seventy-five a minute ; and in women and children it is slightly higher. Though this is the average rate, some people who are quite fit have much slower hearts. We are told that Napoleon's heart only worked at the rate of forty beats a minute. Comparing animals of very different size, the elephant's heart is said to beat only five times a minute —it seems it might not be too easy to count an elephant's pulse !—whilst mice and canaries have hearts that beat several hundred times a minute.

The vessels carrying the blood from the heart are called arteries, and those carrying it to the heart are called veins. The arteries are thick-walled and remain open even when empty of blood. They are lined with a layer of very smooth, thin, flattened cells, which, by preventing friction, helps the blood to flow easily. Below this layer is the main part of the wall of the vessel, made of a mixture of unstriped muscle and elastic tissue. When the heart contracts, or beats and drives blood out from the ventricle into the artery, the artery, being elastic, expands to accommodate the extra blood. When the pressure in the heart falls owing to relaxation of its muscle, the valves at the entrance to the artery close, so that the blood cannot get back from the artery to the heart. The blood is thus driven forward in waves, which cause the arteries to expand as they pass. This artery expansion is known as the pulse. As often as a blood-wave surges from the heart, there is a corresponding expansion at every point in the artery ; so when we count the pulse we also count the rate at which the heart is beating or contracting.

Passing away from the heart, the arteries divide and sub-divide, like the branches of a tree ; first into smaller and smaller arteries ; then into arterioles, and, finally, into capillaries, the smallest blood-vessels in the body (so called from *capilla*, a hair). The capillaries are, in reality, much smaller than hairs and very many capillaries could be accommodated in something the size of a hair. Every time there is a division, the resultant branches are smaller than the parent one ; but their cross section is greater, so the capacity of the blood-vessels increases at every division. By the time the smallest vessels of all are formed the 'bed' is about seven hundred times as great as that of the largest artery, the aorta ; and if they were all in use at the same time the rate of flow in them would, of course, be only one-seven-hundredth of that in the aorta. But if all of them were open at once they could accommodate more than all the blood of the body and so the circulation would stop—more especially since the greater part of the 'bed' of the capillaries is in the abdominal organs below the level of the heart. The capillaries, like the fibres which maintain ‘ tone ’ in the muscles, work in shifts, so that some of them are always closed. But enough of them are open at any one time for the flow through them to be slow.

In the arterioles the lining membrane is still there, but all that is left of the other part of the wall are a few muscle fibres. Like all muscles they are supplied by nerve-fibres and can be made to contract or relax, and so alter the calibre of the vessels. The nerves which make them smaller are called *vaso-constrictors,* and those that make them wider *vaso-dilators.* In the capillaries the only part of the wall left is the lining.

According as the vessels are constricted or dilated, less or more blood can pass through them : thus the supply of blood to any particular part of the body can be regulated. When food is being digested, for example, more blood is needed in the alimentary region. This is often supplied at the expense of the skin, and it is very common for people to feel ‘ shivery ’ after eating a large meal. When the muscles are working they need more blood, and the body is in a difficulty if this happens just after food has been taken and the blood is needed also for digestion. The muscles have to have it, however, and so digestion is held up ; for this reason it is better not to take violent exercise too soon after a meal, especially as the extra heat that is made in the muscles has to be got rid of, and this involves the skin being flushed and its vessels dilated. It seems particularly unsafe to swim or bathe until at least an hour after food, and if the meal has been a heavy one it is better to wait two hours.

The balancing of the claims of the different parts of the body can only be done by the central nervous system, which receives and sends messages from and to all parts. In the medulla there is a centre called the *vaso-motor centre* which regulates the size of the blood-vessels in the different organs and also controls the actions on the heart of two sets of nerves, the inhibitor and the accelerator. Generally the heart is being held a little in check ; but in excitement this restraint goes and the accelerator comes into play, causing the rapid beating so typical of excitement. On the other hand, sudden shock will sometimes stimulate the inhibitor nerve so powerfully that the heart stops altogether. When this happens the circulation stops, no blood gets up to the brain and the person ' faints ' or loses consciousness. The heart soon begins to beat again, but it will always help matters for a fainting person, or someone who feels faint, to have the head down, below the level of the heart, so that the force of gravity will send blood *to* the brain instead of tending to send it in the opposite direction—as it does in the normal position. If a person does actually faint he will almost certainly fall, and in the lying-down position gravity will no longer act in preventing a proper supply of blood to the heart and thence to the brain, and so the person naturally recovers.

The capillaries with their very thin walls and slow flow of blood give the very best possibilities for exchanges between the blood and the cells. In them oxygen and food materials pass across from the blood into the cells, and carbon dioxide and manufactured and waste substances pass from the cells into the blood.

The blood, after passing through the tissues runs into vessels which reverse the process that went on in the division from arterioles to capillaries. By joining together they gradually make larger and larger vessels which, as they are returning the blood to the heart, are veins. Their walls—even in the case of the largest veins—are never as thick as those of the arteries ; and so they collapse when emptied of blood. But they have something which arteries—except the two big arteries which leave the ventricles of the heart—never have ; and that is valves. (*Fig.* 19). These are pocket-shaped ; and are placed with their open mouths towards the heart so that they offer no obstruction to blood flowing to the heart. If, however, the blood tries to flow in the opposite direction, the valves become filled, their edges meet and the way back is blocked. The more the blood is pushed into them the more firmly do they close the way.

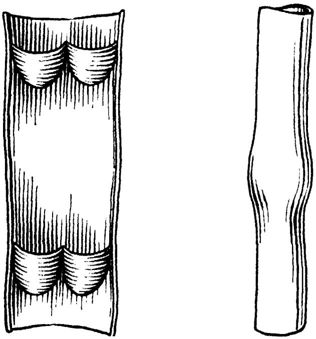

Fig. 19 : Vein (on right) showing position of valve, and vein (on left) cut open to show pocket valves.

The veins of the muscles are specially well-supplied with valves ; and so, when the muscles in contracting press on these vessels, the blood in them, which is prevented by the valves from going back is pushed on towards the heart. Exercise therefore, as is well known to be the case, helps the circulation. Muscles that are still do not help the blood on, and it is a familiar fact that feet and hands tend to swell if they are kept hanging down for some time without contraction of their muscles. In walking, the hands often become unpleasantly swollen—a condition which can be relieved, either by holding the hands up for a little above the level of the heart, or by vigorously contracting the muscles of the fingers, which action will squeeze the blood on.

Nervous control of the blood-vessels is only gradually developed, and so it is necessary to help the circulation in young children or rather, perhaps, not to hinder it.

There should be no constricting clothes on any part of the body, and children should never be long without free movement. When they are sitting their feet should easily touch the ground or some support well within reach: their feet should never 'dangle,' as may be the case in a high chair unless a proper rest for the feet is provided. In sitting, it is always well to have the whole thigh supported, otherwise the edge of the seat pressing on the thigh will tend to interfere with the circulation. Tight garters or suspender-supporters should of course never be worn.

Those having to stand a great deal should be careful not to stand quite still: the different muscles of the legs must be brought into contraction in turn or there may be a tendency towards stagnation of the blood in some of the vessels. If this happens the veins may get too full of blood and become so stretched that the edges of the valves do not meet: in this way varicose veins may be produced.

Contractions of the muscles, then, because of the valves in their veins, help the heart to overcome the effect of gravity. The heart is also greatly helped by messages sent out from the vaso-motor centre. These keep a certain number of the small vessels constricted—particularly in the lower part of the body—so that only a manageable proportion of the blood is lifted to the level of the heart at a time. Blood from the abdominal organs and from the legs has to be lifted; and in a tall person this means quite a considerable amount of work. It is as if a person had to raise a ton of sand: he could do this quite well if it came to him a little at a time, but he would fail completely if he had to push the whole ton up at once. Thus the heart, which can perfectly well manage a reasonable amount of blood at each beat, will be completely defeated if it has to raise too much at one time. This is very important in the standing position, when the amount of blood to be lifted must always be kept well within the heart's capacity if the circulation is to be maintained. If a sudden shock causes a simultaneous letting go of too many of the small vessels, the blood will collect in them and can no longer be lifted to the heart level. There is then not enough blood in the heart to permit it to send a proper supply of blood to the brain, and unconsciousness may be caused, as in the case of the stopping of the heart: the remedy is the same in both cases.

Clearly all these muscles and nerves which are so continuously in action need rest sometimes. The best way of resting them is to have an adequate amount of sleep, lying down: even resting with the 'feet up' will help but not so much as sleep will. That these nerves and muscles are resting when we are in bed can be shown by the queer 'black' sensation that often comes from jumping out of bed very quickly straight from sleep. In this case the nerves to the arterioles are resting, and the vessels are widely opened in more parts than usual and so, on standing up, we get the same kind of effect as was described as coming from a shock. Persons whose nervous systems are in very good condition can put in the contractions of the muscles of the arterioles quickly enough to prevent this; but for most of us, it is wise to allow just a few minutes to elapse between the time of waking and the time of adopting a standing position. Lack of oxygen, and hot humid conditions, tend to weaken vaso-motor control.

The contractions of the arterioles and of the capillaries are responsible for another well-known effect in the circulation: the change from the intermittent, pulsating flow in the arteries to the steady flow in the veins. If a vessel be cut, and the blood spurts out with a bright-red colour, the vessel is an artery; and to stop bleeding, pressure must be applied *between* the cut and the heart. If the blood is purplish in colour and comes out steadily, to stop the bleeding, which this time is from a vein, the pressure has to be applied on the side *away* from the heart. Ordinarily a cut only involves the smaller vessels and the capillaries ; and in this case the bleeding can be stopped quite easily by holding the cut edges together, or by putting on a bandage which prevents the blood from escaping and allows it to clot and so seal up the wound. The bandage and the finger applied to the cut should be clean for reasons already mentioned.

CHAPTER XIII

RESPIRATION

THE muscles, it has been seen, get the energy for the work they do and the heat they make by burning sugar: and not only the muscles, but all the other cells and tissues in the body live by burning. Burning only takes place in the presence of oxygen; and so a constant and adequate supply of oxygen is the first necessity for life. As carbon is always one of the elements burned there is also a steady production of carbon dioxide. The body can be deprived of food and of salts for a matter of weeks—professional fasters have gone without food for as long as six weeks: it can be deprived of water for a matter of hours—sixty or seventy hours, according to the condition of the surrounding atmosphere: but of oxygen for only a matter of minutes. Normally it is hard to hold the breath for a minute; and even after three or four deep breaths, such as are taken before diving if a person wants to be able to remain under the water for more than a few seconds, it is not possible to hold the breath for more than about three minutes. Even that is difficult, and can only be managed by some individuals.

One-fifth of the atmosphere is made up of oxygen, and the body gets its oxygen from the air by way of the lungs. The oxygen, having been taken up by the hæmoglobin of the red blood-corpuscles, is then carried round by the circulating blood and distributed to every part of the body. The carbon dioxide, which is made in the cells, is taken up by the blood and carried back to the lungs. This is the complete process of respiration which is actually carried out in two stages. The first, or external respiration, takes place in the lungs, where oxygen is taken up and carbon dioxide given out ; and the second, or internal, in the tissues between the cells and the blood, where the exchange is in the reverse direction.

The respiratory apparatus comprises the lungs and the passages leading to them (mouth, nose, larynx, trachea, bronchial tubes) and in addition the whole vascular system.

The proper entrance for the air in ordinary breathing is the nostrils, though in very forcible breathing air may have to be breathed in through the mouth as well. Air drawn in through the nose has to pass through twisted passages made by little, thin, curled, scroll-like bones (*Fig.* 11) which are covered with mucous membrane, and the air in passing over this is warmed, cleaned and moistened. The mucous membrane is edged with cells at whose outer borders are *cilia,* fine, hair-like projections which move in such a way as to create a current down the nose. The mucous membranes secrete a sticky, viscid substance which traps small particles, such as dust and microbes, much as sticky fly-papers, trap flies. Very few germs can get past the large surface that has to be passed over by air breathed in through the nostrils ; and the germs that are caught there are often soon killed, so that nose-breathing is one of the greatest safeguards against colds and a great many other infections. The mucous membrane is also very richly supplied with blood vessels, which warm the air as it comes in. The fluid secretion on the surface moistens the air.

From this we can see how important it is that the air should enter by the nostrils. If it goes through the mouth straight to the trachea it goes too quickly, and arrives in the lungs only partially filtered and warmed and moistened. The nasal passages must therefore be kept clear; and, to prevent mucus secreted in them from collecting there, they must be cleared by blowing the nose: hence the great importance of having handkerchiefs and of using them. In the throat, not far from the openings of the nostrils into the throat, there are glands, tonsils and adenoids, which contain a great number of leucocytes. If the air which strikes on them is cold and dry—as it will be if mouth-breathing is persisted in—they become overgrown and eventually tend to block the openings so much that it is difficult to breathe through the nose at all. We know how hard nose-breathing is when a cold makes the mucous membranes of the scroll-bones swell up and block the passages. Children who suffer from enlargement of these glands get into the habit of breathing through the mouth; and, in consequence, many germs that would normally be stopped in the nasal passages get into their lungs and they suffer very frequently from colds. The continually open mouth also gives an unintelligent look to the face, and in some unexplained way the circulation to the brain seems to be interfered with; so that mouth breathers not only look, but actually tend to become, stupid. Cleaning the nostrils on a foggy day will show how much dirt and dust, which otherwise would get through to the lungs, are trapped in the nose.

In this connection, it is interesting to notice the difference in the quality of the incoming air and the outgoing air. Whereas the former is: (a) 20·96% oxygen, (b) 0·04% carbon dioxide, (c) dusty, (d) dry or moist, according to the weather-conditions and (e) of a temperature varying with that of the outside air; the latter is: (a) about 16% oxygen, (b) about 4% carbon dioxide, (c) free of dust, (d) moist, (e) of the temperature of the body.

Having passed through the larynx, or voice-box, the air gets into the trachea and then into the lungs. The trachea, or wind-pipe is a fairly wide passage stiffened by cartilage to keep it always open. The cartilage is not in the form of a single sheet, because that would make us literally stiff-necked, but in rings. The trachea divides into two bronchi; these into smaller tubes; these into still smaller ones called bronchioles; and, finally, at the end of a tiny bronchiole the passage opens out into the air-sacs or *alveoli*. The lung-tissue is made up of myriads of these alveoli whose walls—so as to be as thin as possible—consist of a single layer of flattened cells, outside which is a network of capillary blood-vessels which are so small that perhaps there is only room for a single blood-corpuscle to pass along. In this way the blood in the

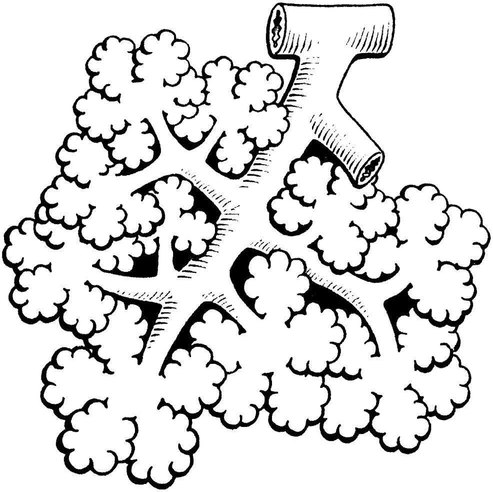

Fig. 20: Alveoli of Lung.

capillaries is only separated from the air in the alveolus by two very thin layers: the flattened cells of the alveolus, spread out to form a very thin basement layer, and those of the capillary wall. Across this very thin membrane gases can pass very quickly; and so oxygen goes into the blood of the capillaries from the air which has been drawn into the alveoli during inspiration, and carbon dioxide passes from the blood into the alveoli. This air is then forced, by expiration, out of the alveoli back into the atmosphere, and so a continuous exchange of oxygen and carbon dioxide takes place. For quick exchanges the great necessity is plenty of surface; and this need has been marvellously provided in the lungs by the arrangement of the alveoli, which are rather like a bunch of grapes would be if each grape as well as the stalk leading to it were hollow (*Fig.* 20). In this simile the stalks would represent the finest of the air-passages. If we could take the skins off the 'grapes', so to speak, and flatten them out into a single sheet it would be large enough to cover nearly half a tennis court and the capillaries in the lungs, if stretched out into a single little tube, would reach right across the Atlantic. It is quite clear, therefore, that a really enormous amount of surface is exposed in the comparatively small space of the chest.

An instance of the speed with which gases *can* pass into the lungs is sometimes seen in a coal mine. A gas called 'choke damp' gets collected in between the seams of coal, and then when an opening is made it will come out and collect into pockets in cavities in the coal. If a miner walks into one of these cavities he will immediately drop unconscious, because the oxygen which is in the blood in his lungs passes out very quickly from the blood into the lungs, where there is no longer air but only the choke damp. He comes round directly he falls outside the pocket and gets air—

and so oxygen—into his lungs again ; but everything has happened so quickly that he has no time to realise how it happened, and finding himself on the ground, feels he has been knocked down by one of his mates.

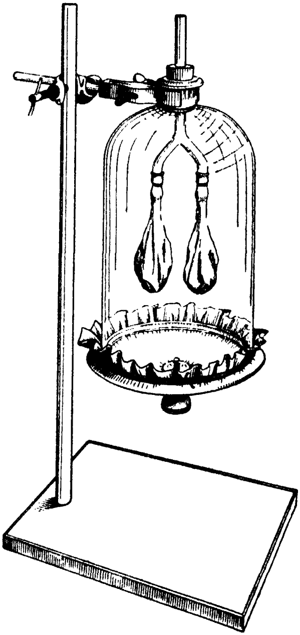

Fig. 21 :

Apparatus to illustrate change of size of elastic lungs, with change in size of chest cavity. The rubber membrane at the bottom represents the diaphragm, when this is pulled down the balloons enlarge and air is drawn in ; when it is pushed up, the balloons collapse and air is pushed out.

The next point to consider is : what makes the air go in to and out of the lungs ? It is the movements of the chest-walls : the movements of inspiration and expiration. The lungs are suspended inside an air-tight box, the chest, in such a way that no air can get between the lungs and the chest wall and the only way air can gain entrance is by the lungs. So, if the cavity inside which the lungs are suspended enlarges, the lungs must follow the movement and enlarge too; and if it contracts, they must contract (*Fig.* 21). This is made possible by the elasticity of the lungs.

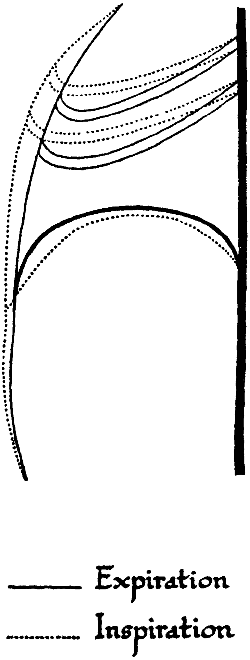

Fig. 22: Showing position of ribs and diaphragm in inspiration and expiration.

The chest is bounded at the back, front and sides by the spine, ribs and sternum, and the muscles attached to these bones; and at the bottom by a stout sheet of muscle, the diaphragm. In inspiration the ribs are lifted, and, as at rest they slope downwards, this increases the distance between the spine and the sternum; and so increases the front-to-back diameter. At the same time the ribs turn outwards, bucket-handle movement, and so increase the side-to-side diameter. The vertical diameter is increased by the contraction and lowering of the diaphragm. (*Fig.* 22.) From the above it is clear that breathing is a muscular movement.

Quite big changes in the volume of air taken in can be produced by specially exerting the muscles. In ordinary quiet breathing about 500 cc. of air are moved in and out: this is called the 'tidal air.' With an extra big effort another 1,500 cc. can be breathed in after an ordinary inspiration, and the same amount breathed out at the end of an extra expiration. These three together, the extra 1,500 cc. of inspired air which is called complemental air, plus the 500 cc. of tidal air, plus the 1,500 cc. of extra expired air or supplemental air, together make 3,500 cc. which is called the *vital capacity*. The chest's capacity for air seems to depend chiefly on the elasticity of the chest, and is not helped by a very great development of the muscles of respiration. A large vital capacity is best developed by breathing-exercises or by the natural forced breathing caused by very vigorous exercise. When all the air that can be forced out has been expired, there is left in the lungs about another 1,500 cc. of residual air. This added to the 3,500 cc. vital capacity makes the lung capacity. Even in quiet breathing many muscles are involved, but in violent forced breathing nearly every muscle in the body is brought into play to bring about either inspiraton or expiration. Usually there is very little active muscular action in expiration: it is more a return to the resting position after inspiration.

If a great many muscles are involved they must, of course, all work together in harmony. If the ribs were lifted to the inspiratory position at the same time that the diaphragm came up to its resting expiratory position, a great part of the effort would be lost. All the muscles, then, have to be kept informed of one another's position and have to work at just the right moment and to just the right extent. This naturally means control from the central nervous system. The final centre of control is in the medulla; and if the brain were destroyed at that level then regular effective breathing would stop.

The working of this centre is regulated in two ways: partly by all sorts of impulses (coming to its cells by afferent nerves), which are sorted and then passed out by efferent nerves to the appropriate muscles of the chest and abdomen; and partly by the quality of the blood which is supplied to the brain. The regular rhythm of respiration is largely maintained by messages coming up from the lungs along the vagus nerves, but other nerve-messages can affect the centre. Excitement and emotions will cause messages, which may make a person breathe more quickly or hold his breath, to come from the higher centres of the brain. An irritation in the throat will probably produce the quick, forced expiration which makes a cough; or one in the nose, the special expiration, the sneeze.

It may be well to point out here the obvious necessity for putting the handkerchief or hand in front of the mouth or nose in coughing or sneezing. If there are germs in the respiratory passages these will be carried out in the air, and moisture forcibly ejected may be carried some distance and be breathed in by some other person, and so perhaps pass on an infection. It is very important to keep as far away as possible from others when suffering from a cold. At a distance of about four feet the germs in the expired air have generally become so thinned out, that risk of infection is much cut down. But if heads are at all close together the other person gets a very concentrated dose of germs and may very likely fall a victim.

A person who is hurt generally makes a quick inspiration, and it is difficult to imagine anyone breathing out under those circumstances. When there is swallowing to be done breathing stops altogether till the food or liquid has passed the dangerous region where the air-passage divides off from the food-passage. Occasionally something very light, which does not stimulate the act of swallowing and so stop breathing, does get in—a crumb 'goes the wrong way' and then there is a tremendous business of coughing to get it out!

The quality of the blood going to the brain is of great importance. The proportion of oxygen to carbon dioxide in the blood is a most important factor in respiration and, in this connection, nature provides an ingenious safeguard. Since oxygen is so important for life it might have been expected that the respiratory centre would be very sensitive to small changes in the quantity of oxygen. If we think for a moment, however, we shall see that it would be very dangerous to life if quite small variations in the oxygen mattered so much that they could lead to disordered breathing. As a matter of actual fact, the hæmoglobin is so wonderfully able to pick up oxygen that there is not any danger of an acute shortage until the air breathed contains only about half the usual amount of oxygen. All the same, it is most important to keep up a good supply of oxygen, and this is assured by making the centre exquisitely sensitive to quite small increases in the quantity of carbon dioxide. If this gas increases in the lungs (and so in the blood) by even so little as 0·2 %, the centre is immediately stimulated to produce deeper and quicker respirations so that the extra carbon dioxide can be washed out. But if more air is breathed in, to wash out the carbon dioxide more oxygen must be brought in too ; and as carbon dioxide is only made by burning carbon and so using up oxygen, an increased supply of oxygen is assured whenever it is being used up more quickly.

The amount of carbon dioxide in the lungs is in this way kept extraordinarily constant. Directly more is made, as in exercise, some of this excess will be carried to the brain, and this will increase the depth of breathing which will wash out more carbon dioxide and at the same time bring more fresh air into the lungs.

But if the oxygen is cut down by more than half, then the brain-centre will be stimulated very vigorously because a proper supply of oxygen is vital for life. Under ordinary conditions the body would never get to this state, because even in badly-ventilated rooms there are enough cracks and chinks as a rule for some air to be exchanged and so keep up the oxygen supply. But when the human body reaches very great altitudes difficulties are bound to arise. Thus, when the men who in 1933 attempted to climb Mt. Everest reached a level of 27,000 feet, breathing became extremely difficult. At that height it is so difficult to get enough oxygen that the climbers tell us that they had to take five or six breaths for every step they took. Even at much lower levels such as 15,000 feet, people can suffer great distress for lack of oxygen. In such cases greater distress is suffered when the ascent has been rapidly made. To be comfortable at such heights, it is necessary either to become acclimatised by ascending gradually, or else to breathe oxygen from a cylinder. The aviators who flew over Mount Everest were equipped with special cylinders and special valves, which could be heated so that the moisture in the expired air would not freeze and thus stop the oxygen supply.

When an individual does not get enough oxygen the proper working of the nervous system is very much disturbed. If the decrease in the oxygen-supply occurs suddenly, there may be violent sickness (such as the ‘ mountain-sickness ’ of climbers), diarrhoea, and very confused thinking.

Luckily it is not necessary to get to the top of Mt. Blanc or some other very high mountain, or to go up to great heights in an aeroplane, to make experiments as to the effects of lack of oxygen. Steel chambers in which the pressure can be cut down to any required level can be used. The persons to be tested go into the chamber and then, when they are shut in, the pressure is lowered—or, as the people inside prefer to put it, they ‘ go up ’ to a certain level.

As the pressure is lowered, the mental faculties become dulled, the simplest sums cannot be done correctly, spelling gets very queer and writing illegible ; though because of the cutting down of the oxygen supply to the brain, which then ceases to function properly, the subjects do not realise that there is any difference. If the pressure is reduced very much the muscles become paralysed ; the person who is being tested can no longer stand ; the face goes very blue and all kinds of sensation are blunted. The story is told of an investigator asking another if he was looking blue ; on being given a mirror, he looked very intently at the back of the mirror for a long time ; and neither of them seemed to think that there was anything wrong ! The men who went on the Mt. Everest flight were all tested in such a chamber.

On the re-introduction of air into the chamber, the subjects say they suddenly become aware of things that they have failed to notice ; and that all sorts of sensations seem very vivid, colours intensely bright and sounds very loud. Most of us are unlikely to get into circumstances where there is a real shortage of oxygen, but, from observations that have been made lately, it appears that quite a small deficiency maintained for long will gradually come to have really serious effects. The continuous breathing of vitiated, stagnant air will produce these effects ; as will also, a habit of very shallow breathing which is often a quick breathing. That is why it is good to have plenty of exercise out of doors, or, if this is difficult, at least to do breathing exercises at an open window. As people naturally make use of a much more shallow breathing when asleep, it is particularly important to have windows open in a bedroom or any sleeping-room.

Persons suffering from anæmia will also run a risk of poor oxygen-supplies ; and headache and mental weariness are common effects of anæmia. Interference with the free movement of the respiratory muscles—such as will be brought about by tight clothes, or by maintaining a stooping position with rounded shoulders and contracted chest, or even by wearing too many and too heavy clothes—will make it hard to get a proper amount of air into the lungs. Too little exercise and too much sitting will interfere in another way by causing the blood to circulate so sluggishly that the cells will not get enough oxygen brought to them.

There is in our modern life another way too, and an acute one, of going short of oxygen—in fact short enough to be fatal—and that is to breathe in either coal-gas or the discharge from the exhaust of a motor car. In both of these there is carbon monoxide, a gas that is produced instead of carbon dioxide when carbon is burnt in the presence of a shortage of oxygen. The carbon monoxide is not poisonous in itself ; but unfortunately hæmoglobin, on which we depend for our oxygen, if it has a choice of joining up either with oxygen or carbon monoxide, will always choose the carbon monoxide, and then there is nothing to take the oxygen round to the cells, which, if kept without oxygen, will die.

That is why there must always be ventilation to the outside air, both in a room where gas is supplied or where it is being burnt, and in a garage. If there is plenty of air, there is no danger ; but if there is not, then the carbon monoxide of the gas or of the exhaust-air will join up with the hæmoglobin. Gas companies will never put in a geyser without a vent to the outside-air, through which the waste gases can escape ; and people ought to be very careful that this safeguard is made use of. In addition, it is as well to leave either the window or the door of the bathroom open while the geyser is alight, and to turn off the gas before getting into the bath. Care must be taken that gas-taps are in such positions that they cannot be turned on by little children. Gas is so convenient and so useful for domestic purposes and so safe when properly used that everyone should be instructed how to use it in such a way as to run no risks. A motor car engine should never be kept running in a closed garage or fatal consequences may follow.

Carbon dioxide, as has been seen, is being produced continually in the muscles and in the rest of the body by the oxidation of carbon. Some of it is necessary to keep the breathing going properly, but the excess is got rid of through the lungs. If too much is got rid of, breathing will stop until enough carbon dioxide has again accumulated or until the oxygen is brought down to the level at which its shortage will act as a stimulant. If about fifteen or twenty very deep and very powerful respirations are quickly taken there will be no inclination to breathe for perhaps as long as a minute because of the excessive washing out of carbon dioxide ; and there is a delay until this has come up again to the proper level. Too much carbon dioxide will act as a kind of anæsthetic and actually poison the respiratory centre. In more moderate amounts it causes headache, and flushing of the skin capillaries ; symptoms often met with in a full railway-carriage if there is no outside air coming in.

Men working under water, divers locating wrecks, men laying cables and building bridges all have to have air pumped to them at a pressure as great as that of the water surrounding them. This pumping sends gases into solution in the body-fluids, in the same sort of way that carbon dioxide is put into soda water under pressure. Such men have to come up to the surface very slowly or the gases would be given off in bubbles as they are from soda water when it escapes from the bottle. If these bubbles get into the capillaries they may give rise to extreme distress by blocking the circulation. These examples show how necessary it is for divers and engineers to know a great deal about the way breathing is carried on.

Sometimes it is necessary to carry out artificial respiration on people who have fallen into the water or who have been poisoned by carbon monoxide from staying in a closed garage with the engine of a motor car going, or by an escape of gas in mines. These people have stopped breathing, and air has to be got in and out of their lungs in some other way. There are various methods of artificial respiration of which two the Schafer and the 'Tilt' methods will be briefl described. In the Schafer method the person to be resuscitated is placed in the prone position, with the head turned sideways to leave the mouth free, and a folded coat or rug is placed under the chest. The operator kneels at the side or better still astride the subject, and places his hands on the back below the shoulder blades, with fingers outwards and palms towards one another near the middle of the back. He then leans forward slowly bringing his weight on to his hands—not so violently as to run a risk of damaging the ribs. This compresses the chest and a considerab volume of air is forced out. The operator then straightens his body and takes its weight off his hands, the elasticity of the chest walls of the subject comes into play, the cavity is enlarged and air is drawn in. This process is repeated about 15–20 times a minute. The advantages of the method are that a good volume of air is exchanged at each operation and that the process is not so fatiguing for the rescuer but that he can continue it for a long time. Sometimes natural breathing begins after two hours or more of artificial respiration.

The 'Tilting' method which is the newest one, has the advantage of being even less fatiguing to the operator, but it does require some apparatus—ambulance stations will probably have the equipment, but any flat surface that will support the unconscious person and can be arranged as a see-saw will suffice. The person is strapped on the board so that he cannot slip and the support is rocked 15–20 times a minute. In the head down position the weight of the abdominal organs comes against the diaphragm and pushes it up into the expiratory position and air is driven out. With the head up the reverse process takes place, gravity pulls the organs down and the diaphragm escends into the inspiratory position with a conequent inrush of air. With an easily working tilting oard very little muscular exertion is required. These vo methods are undoubtedly the most satisfactory r carrying out the prolonged artificial respiration hich may be necessary and knowledge of them will be ery useful in an emergency.

CHAPTER XIV

DIGESTION

We have already considered the way in which the body gets its necessary oxygen and the process by which the carbon dioxide made in the cells is eliminated. Now we must find out how that carbon dioxide is made and how our own supplies of carbon fuel are obtained.

The fuel is supplied by the food we eat. We also know that when a food, such as meat or bread, is strongly heated it becomes a mass of charcoal: that proves that carbon is contained in the food. Charcoal is useless as a food because it cannot be absorbed nor can it be burnt by the cells. It must be given to the cells in the form of certain carbon compounds. Some of these compounds are present in the food as we eat it, but usually the various ingredients of food must be changed before they pass into the blood stream to be taken to all the cells of the body. The food, in addition to its use as a fuel for the body, also supplies the material required by cells for their growth and from which new cells are formed to replace those that are worn out.

On investigating foods in general, one finds that the same kinds of chemical compounds turn up over and over again: in fact, the value of any food is chiefly dependent upon whether it supplies one or more of a certain very limited number of food constituents; each of which can be digested and absorbed and used by the cells for oxidation and energy production, or for growth and repair of the tissues themselves.

Table I shows the five constituents which continually appear as components of ordinary foods.

TABLE I.

Food Constituent	Use (Fuel or body builder)	Common Foods containing food constituent
WATER	Body builder. The human body is 66% water	All foods, both solids and liquids, contain water. Milk is 88% water. Boiled beef is 57% water. Cucumber is 96% water.
INORGANIC CONSTITUENTS	Body builders	All natural animal and vegetable foods contain them. Common salt (sodium chloride) is the only inorganic salt deliberately added to food. Milk and cheese are especially good sources of calcium and phosphorus. Egg-yolk, meat and green vegetables provide iron.
FATS	Fuels and also Body builders	Fat meat, dripping, suet, many fish, egg-yolk, milk, butter, cream, nuts, vegetable oils.
CARBOHYDRATES (Sugars and Starches)	Fuels	Cane Sugar. Sugar of milk. Starch in wheat flour, rice, peas, oatmeal and potatoes.
PROTEINS	Body builders and also Fuels	Solid of egg-white and lean of meat is nearly pure protein. Milk is 3–4% Protein. Cheddar Cheese is 33% Protein. Pea-flour is 28% Protein

Water. It can easily be shown that food contains a considerable quantity of water. If a food is left in an oven the food shrinks and loses weight as the water evaporates and the food dries. Another way of showing that a food contains water is to squeeze the food. An apparently solid food, such as a raw potato, if cut into pieces, minced and the minced material put into a muslin bag and pressed in an ordinary potato-masher, will give, even by this rough-and-ready method, a volume of water that is about half the volume of the original potato. In the muslin bag is left a fibrous mass almost free of water.

Inorganic Constituents. Calcium, phosphorus, iron, sulphur, iodine and other elements may be present in food as inorganic salts or may be combined with one of the carbon-containing constituents. Milk contains phosphorus as inorganic salts (phosphates), but it also contains phosphorus in combination in one of its chief proteins (caseinogen).

Fats. Fats may be taken in the pure form as an oil (salad oil) or as part of the food. Cream, and milk-products, such as butter and cheese, are rich in fat. The chief function of fats is to serve as fuels, but in addition they provide for the body certain fatty substances required in the formation of cell protoplasm.

Carbohydrates. The sugars and starches, particularly the latter, form a large part of what we eat; and the nutritive value of such staple foods as bread and potatoes is in the main due to the high percentage of starch each contains.

Proteins. Protein is essentially a body builder, because it contains nitrogen, and is the only substance which we can use for supplying nitrogen to the cells. All cells require nitrogen for the building up of their own cell-protein. After water, protein is the chief constituent of most tissues. Protein is also a fuel, since it contains carbon and can be oxidised in the body to give carbon dioxide and at the same time liberate energy.

Water and inorganic salts pass unchanged into the blood stream; but fats, proteins, starch and most sugars in food must be converted into simple substances before they can be absorbed. This change in food is digestion and makes the constituents soluble and diffusible. Digestion is brought about by the action of ferments or enzymes. There are many well-known enzymes which act outside the body. The souring of milk is due to an enzyme contained in certain bacteria which changes the sugar of the milk into lactic acid. Other bacteria contain enzymes which decompose the constituents of meat, producing unpleasant smelling substances and turning the meat bad. A very familiar example of ferment action is that of yeast on sugar. Yeast cells contain many enzymes, some of which change starch and cane sugar into fermentable sugar; and this in its turn is changed into alcohol and carbon dioxide.

The enzymes of the body which act upon food are made in various special cells grouped to form definite digestive glands. Food passes from the mouth through a long canal into which these glands pour their digestive juices. The canal is called the *Alimentary Tract* and this, together with the digestive glands, forms the *Digestive System.* Each enzyme of a digestive juice acts upon one food constituent only, and many of the enzymes only change the constituent to an intermediate stage and the final chemical change is brought about by another enzyme at a later stage in digestion.

The carbohydrates of food can only be used by the body cells in the form of simple sugars, the chief of which is glucose (grape-sugar or dextrose). All the starch and complex sugars of food are changed by the digestive enzymes into glucose and other simple sugars and in that form are absorbed.

Fats, whether animal or vegetable, all undergo the same kind of chemical change, and are converted into glycerine and the particular fatty acids which were combined with the glycerine to form the undigested fat.

The changes which occur in the digestion of food proteins are such that these complicated chemical substances are split up into a number of much simpler substances, which can be absorbed and carried to the cells of the body and rearranged to form the protein of the cell-protoplasm. It is as if one knocked down several brick houses and then used the bricks to build new houses quite different in appearance from the old ones. The simple substances into which proteins are split contain nitrogen and are called *amino acids*.

Food, after it has been chewed and swallowed, passes into the *gullet* (*œsophagus*) which lies just behind the windpipe and opens at its lower end into the *stomach*. The stomach is a muscular bag on the left side of the abdomen situated just under the diaphragm. The bag stretches to hold the amount of food entering it, and because it lies just below the heart one may be misled by indigestion into believing that there is something wrong with the heart. Food passes from the stomach into twenty feet of a coiled, narrow, muscular tube (*small intestine*) and then into five feet of wider tubing (*large intestine*). The *appendix* is a small tubular pouch of the large intestine on the right side close to the opening of the small intestine. The large intestine opens to the exterior by the *anus*, which is normally kept closed by a ring of muscle.

Digestion of food starts directly it is put into the mouth. A small quantity of liquid is continually being poured into the mouth from glands and sometimes such a quantity is produced that we say the mouth is watering. This liquid (*saliva*) digests cooked starch and if one chews thoroughly the saliva gets well mixed with the food and the enzyme-action continues for quite a long time after the material has reached the stomach. Saliva also makes the food slippery. The muscular walls of the stomach contract in such a way as to move the food about and mix it with the *gastric juice* which is formed by the gland cells in the lining walls of the stomach. The juice contains an enzyme which starts the digestion of proteins and another enzyme (*rennin*) which curdles milk. Gastric juice is acid and probably destroys some of the germs swallowed with the food. After about an hour the ring of muscle which keeps the opening into the intestine closed, relaxes and a little of the semi-digested food (*chyme*) passes into the first part of the small intestine. This passage of chyme continues at intervals until the stomach is empty and for an average meal the emptying takes about four hours. Sometimes the stomach is "upset" and the contractions may force the contents in the reverse direction to normal and the individual is sick.

In the small intestine three juices act on the chyme and make it even more liquid. *Pancreatic juice*, which comes from the *pancreatic gland*, contains enzymes which act on starch, protein and fats; and the digestive changes in food are completed by numerous enzymes in the *intestinal juice*, which is made by cells of glands in the wall of the intestine itself. The *liver* which is the largest gland in the body steadily manufactures bile (*gall*). This liquid is stored in the gall-bladder, and during digestion some of this bile is squeezed into the intestine. Bile contains no enzymes but it evidently helps the other digestive juices, since if it is absent, digestion, especially of fat, is less satisfactory.

The lining wall of the intestine is soft and is richly supplied with tiny blood and lymph capillaries. The surface for absorption is tremendously increased by a ridging of the soft lining and in the small intestine it is raised up into very tiny finger-like projections which make the inside surface feel like velvet to the touch.

In the large intestine the contents are acted upon by the enzymes of bacteria swallowed with the food; water is absorbed and the contents become less liquid. As the food moves along the intestine, worn out cells of the lining coat are gently rubbed off, and so also help to make the final residue more solid. The residue is coloured by the bile and is given an unpleasant smell by products of bacterial action.

Curious waves of muscular contraction (*peristalsis*) move the contents along the intestine in much the same way that an orange could be forced along the leg of a woollen stocking by pushing the orange from behind with the hand. The passage of food along the whole length of the alimentary canal takes about eighteen hours. When some of the unwanted residue gets into the lower end of the large intestine (*rectum*) messages pass to the spinal cord, causing a reflex contraction which empties the bowel, unless the anus is kept closed. The power of regulating the opening of the anus is only acquired after birth, during the early years of childhood. A residue of small bulk does not readily stimulate the rectum to empty itself and such a residue may be produced when feeble peristalsis allows a longer time for absorption of water in the large intestine.

The various glands of the body may be excited to increased activity by nerves or by substances present in the blood circulating through the glands. We find that the digestive glands are stimulated in both these ways. Hunger and appetite cause an outpouring of saliva and of gastric juice when one sees, smells and tastes food. This 'appetite-juice' starts digestion and causes the formation of substances which, when they are absorbed into the blood, bring about the production of more gastric juice and of the various juices acting in the intestine. Thus a way is provided for the continued production of digestive juices, while there is still food in the canal, after appetite has been satisfied. The production of appetite-juice is very readily disturbed by the emotions. Everyone knows how dry the mouth can become when one is nervous or how copiously it may water at the mere thought of a delicious food. A good flow of appetite-juice is encouraged by eating tasty food, served nicely in quiet surroundings.

The blood brings to the glands and muscle of the digestive system the materials and oxygen necessary for their increased activity during digestion. The sleepiness which follows after a heavy meal is felt because the greater demand for blood by the digestive system reduces the amount of blood serving the brain. If the skeletal muscles are working vigorously during digestion less blood is available for digestion and this function may be upset. This explains why it is wise to sit quietly at meal time. ' After dinner rest awhile ' is a really sound health rule.

The movements of the alimentary canal are also influenced by the emotions. When barium salts are added to food, the passage of the food along the canal can be observed by means of X-Rays. If a cat is given milk containing these salts one finds that where the cat sees a dog with whom it is friendly no change occurs in the movements of digestion, but if it sees a dog that it does not know or with whom it is angry, at once the movements will cease. It is evident that anger or worry may quite seriously upset digestive processes, and that contentment and quiet during meals help towards good health.

During absorption, water, salts, the simple sugars and the amino acids pass through the lining wall of the intestines into the blood capillaries, and are carried through the liver into the general circulation.

The digested fat passes into lymph capillaries and is carried by the lymph straight into the blood returning to the heart.

Food can only be considered as having got into the body when it reaches the circulating blood and only then is it of use to us as fuels and body builders. Much research has been needed to give us an idea of the chemical changes that take place when the absorbed materials circulate in the body fluids and reach the tissues. We speak of the various changes which occur in the cells as *metabolism*.

Fats and carbohydrates, being fuels, ought to be capable of being stored, so that between meals and when there is some sudden call for an increased expenditure of energy we have available reserve fuel. The main store of fat is under the skin. It is not only a store but serves another useful purpose since fat reduces the rate at which heat is lost from the surface of the body. It is a generally recognised fact that thin people 'feel the cold.'

Sugar is stored in two ways. In the liver and muscles it is stored as an insoluble carbohydrate called glycogen. In many respects glycogen corresponds to the starch, which is the carbohydrate store of plants; and so it is sometimes spoken of as animal starch. About half of this store is found in the liver. If more sugar is taken than can be stored as glycogen and oxidised by the cells, sugar is changed into fat and stored in that form and the weight of the body increases.

The amino acids circulating in the blood after digestion of proteins, are taken up as required by the cells and manufactured into their own special proteins. Although protein is an essential food material, it cannot be stored. The amino acids set free when cell proteins are broken down and any amino acids absorbed from the alimentary canal and not used, are all turned out from the body. Those to be turned out are changed by the liver into various substances (the chief of which is a nitrogen containing compound called *urea*), and are removed from the blood by the kidneys. Many different amino acids are needed for the building up of the numerous complex substances manufactured by the cells of the body. Some of these complex substances can be formed from a variety of different amino acids but others can only be formed if certain particular amino acids are supplied. These are termed *essential amino acids* and it is absolutely necessary that the food-protein should contain an adequate supply of such amino acids. A protein rich in essential amino acids is sometimes spoken of as an A1 Protein. In general the animal proteins are richer in essential amino acids than are vegetable proteins.

Water and inorganic constituents are not changed in digestion and play a very important part in metabolism. Water is needed to supply the liquid part of all the body fluids, such as the blood and digestive juices. Water forms a large part of the living protoplasm of every cell; it is the means by which substances in solution pass from the alimentary canal into the circulating blood, and by which substances in solution enter and leave the tissue-cells. It is also essential for the processes of temperature regulation. It is true that some water is made when any hydrogen-containing food is oxidised but the amount produced in this way is not sufficient to supply our daily need for water and we must take a considerable amount of fluid to compensate for its loss. A camel can be used for a long journey lasting over many days in the desert because it possesses in its hump a large reserve store of fat which is capable of yielding much water to the camel as the fat is oxidised.

The importance of the inorganic constituents lies in the fact that besides their general use in building up protoplasm, certain of them are required for special purposes. The ability of hæmoglobin to pick up and carry oxygen is due to the iron contained in it. Calcium compounds improve the contracting power of muscle, enable blood to clot when that liquid escapes from a blood-vessel; and, together with phosphorus provides the main part of the inorganic material of bones and teeth. Iodine is needed by the thyroid gland; and without it neither physical nor mental development can be normal.

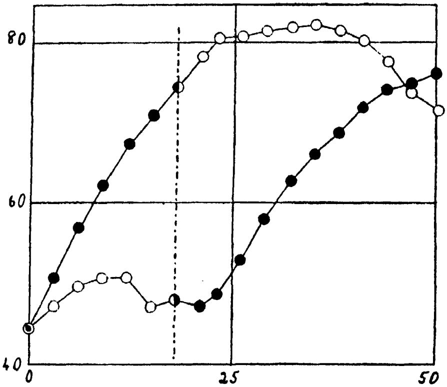

Fig. 23

Lower curve (up to eighteenth day), eight male rats upon pure dietary; upper curve, eight similar rats taking 3 c.cm. of milk each a day. On the eighteenth day, marked by vertical dotted line, the milk was transferred from one set to the other. Average weight in gms., vertical; time, horizontal. (Reproduced by permission from the *Journal of Physiology*, 1912, **44**, 433.)

One might imagine that if energy producing and body building constituents were supplied in the food, all would be well. Professor Frederick Gowland Hopkins, working in Cambridge, noted as early as 1906 that " no animal can live upon a mixture of pure protein, fat and carbohydrate, and even when the necessary inorganic material is carefully supplied, the animal still cannot flourish." In 1912 he published the results of experiments which had extended over several years. Young rats fed on a mixture containing pure food constituents soon ceased to grow and began to decline. Another group of rats fed on a similar mixture, but receiving in addition a tiny ration of milk daily, continued to grow normally. When the diet of the two groups was changed over, the first group soon began to recover and grow again, whereas the second group ceased to grow and began to lose weight. Figure 23 shows how the growth-curves of these two groups of rats were affected by the presence or absence of milk.

These experiments, together with others carried out by investigators in many different parts of the world, showed us that we need something else in our food, in addition to energy producing and body building material, for normal health and growth.

These accessory food factors have been given the name of *vitamins.* They are usually most active in fresh natural foods; and most of them can only be made by plants. Although we are only just beginning to know something about their chemical composition, we are very well aware of the troubles that occur if vitamins are absent from our food. Such very small quantities of these accessory food factors are required, that they certainly cannot act as fuels, nor directly as body builders; and all we can say is that they must be present in the body for the cells to function properly. Perhaps one might say that they are somewhat like the lubricating oil without which an engine will not run smoothly.

The astonishing thing about vitamins is the fact that very minute quantities of each are apparently required; and yet the health is very seriously affected if that small supply is reduced or cut down altogether.

CHAPTER XV

DIET

THE daily supply of the different foods we eat is usually spoken of as our *diet*. It is generally agreed that the diet should satisfy certain requirements. It should :—

(1) Contain all the various food constituents in properly balanced amounts.

(2) Contain sufficient of the energy producing constituents for the needs of the particular individual.

(3) Contain sufficient protein to compensate for protein breakdown in the cells, and contain some proteins rich in the essential amino acids.

(4) Contain all the different vitamins in sufficient amount to maintain weight and if necessary produce growth.

(5) Contain the necessary inorganic constituents.

(6) Be appetising, digestible and capable of absorption.

(7) Contain material (*roughage*) which will stimulate peristalsis and so assist a daily bowel evacuation ; and some hard material to necessitate vigorous chewing.

(8) *Not* contain injurious substances.

(9) Be in quality and quantity suitable for the needs of the individual concerned according to conditions of age, occupation and climate.

Let us consider each of these requirements in turn and see what standards there are to help us in judging whether or not any particular diet is satisfactory.

1. *Balance of Constituents.*

Certain groups of people and certain races are obliged by local conditions to live on a diet which to our way of thinking is unbalanced, but which in some cases is really quite satisfactory. The Esquimaux, for instance, live almost exclusively on flesh-food (whale and seal), and provide themselves with their energy producing material entirely in the form of protein and fat. In the excessive cold of the Arctic regions, however, a food of high heat-value, such as fat, is a vital necessity; and such a diet is not as unsuitable as at first appears. On the other hand many Eastern native races live almost entirely on cooked rice and have a diet lacking in fat and protein and heavily overloaded with starch. The Japanese and many of the Indians are short people and rather undersized according to Western standards, and it is possible that this is in part due to the fact that their usual diet is so low in protein and vitamins.

Among European races one does not often come across diets that are quite so badly balanced; but, because starchy foods are cheap and filling and fat and protein are expensive, there is always a tendency in a home where there is not much money for the diet to be overloaded with starch. Fortunately our tastes quite often seem to guide us wisely, and in Great Britain at any rate we have got into the habit of eating together certain foods which supplement each other's deficiencies. The starchiness of bread is nicely balanced by the protein and fat of cheese. Boiled bacon contains plenty of fat and protein, but no carbohydrate, and the custom of eating with it beans or pease pudding makes good that lack. By having greens as a second vegetable with meat and potatoes, valuable inorganic constituents, vitamins and roughage are added.

2. *Energy Producing Requirements.*

For health, the energy producing power of the food each day should as nearly as possible balance the loss of heat and expenditure of energy of the individual. The different forms of energy are interchangeable, and therefore in all problems concerned with the intake and expenditure of energy one and the same unit is used.

The particular unit chosen is the heat unit or *calorie.* (One calorie is the amount of heat required to raise one gramme of water through one degree Centigrade.) This is so small a unit that for convenience in calculating food problems the large Calorie or Kilocalorie is usually used. This is equal to a thousand of the small calories and represents the amount of heat required to raise a thousand grammes of water through one degree Centigrade. This large unit is still called a Calorie but is spelt with a capital C. to distinguish it from the little calorie.

To determine what ought to be the energy value of a day's diet we must determine the energy expenditure of the individual for the twenty-four hours.

This can be done in a variety of ways, and Table 2 gives a useful series of average figures for the daily Calorie expenditure at various ages. It is true one must not adhere rigidly to these figures, since our expenditure of energy varies from day to day according to what we are doing and to the temperature of the surrounding atmosphere, but these figures are useful in giving us a general idea of what is our daily Calorie production and so of our needs according to age and sex.

TABLE 2

Age in years.	*Boys.*		*Girls.*	
1	950	*Calories.*	940	*Calories.*
2	1135	,,	1110	,,
3	1275	,,	1230	,,
4	1380	,,	1300	,,
5	1490	,,	1410	,,
6	1600	,,	1520	,,
7	1745	,,	1660	,,
8	1920	,,	1815	,,
9	2110	,,	1990	,,
10	2330	,,	2195	,,
11	2510	,,	2520	,,
12	2735	,,	2860	,,
13	3040	,,	3210	,,
14	3400	,,	3330	,,
15	3855	,,	3235	,,
16	4090	,,	3160	,,
17	3945	,,	3060	,,
18	3730	,,	2950	,,
Adult	Man 3265	,,	Woman 2640	,,

From: Holt and Falls. *American Journal of Diseases of Children*, 1921.

These figures give us the expenditure side of our balance sheet, and we must next find out how we may test the income side, so that we may be sure the two sides agree. Our Calorie income is of course dependent upon our carbon-containing food constituents; and the amount of heat each of these yields when burned or oxidised in the body has been found to be as follows :—

1 gramme Carbohydrate yields 4·1 Calories.
1 gramme Protein yields 4·1 Calories.
1 gramme Fat yields 9·3 Calories.

One ounce is equal to 28·3 grammes, so that the Calorie yield to the body of one ounce of any food ingredient can be obtained by multiplying its gramme Calorie yield by 28·3.

The fact that, weight for weight, fat has more than double the heat producing value of either protein or carbohydrate shows why the excessively fatty diet of the Esquimaux is satisfactory.

The Calorie values for the different food-constituents refer to the pure material; and since most foods are made up of all the different constituents in varying proportions, we can only calculate the Calorie value of the food itself if we know how much of each constituent is present in a given weight of the food. Years of patient research have provided us with the percentage composition of most of the usual foods; and in Table 3 the average figures thus obtained are set out for a few everyday foods.

TABLE 3.

Food.	Percentage-Composition			Calories yielded by 1 ounce. (28·3 grammes).
	Protein.	Sugar & Starch.	Fat.	
Apple (raw) ..	0·40	12·50	0·50	15+
Banana (without skin)	1·50	22·90	0·70	28+
Boiled beef ..	34·00	—	7·50	56+
Boiled beetroot	—	8·00	—	9—
Boiled cod ..	21·67	—	0·27	30—
Boiled eel ..	16·68	—	17·38	64—
Boiled herring ..	26·46	—	9·96	55—
Boiled onions ..	—	5·40	—	6—
Boiled potatoes	2·50	20·30	0·10	25—
Boiled rice ..	5·00	41·90	0·10	50—
Boiled sago ..	1·38	9·37	0·04	12—
Butter	2·0		75·00	200—

Food.	Percentage-Composition			Calories yielded by 1 ounce. (28·3 grammes).
	Protein	Sugar & Starch.	Fat.	
Cane sugar ..	—	93·33	—	108·7
Cheese (American)	32·90	—	31·00	118+
Cooked cabbage	0·60	0·40	0·10	1+
Cooked tomatoes	1·00	0·10	0·20	2—
Dried dates ..	4·40	65·70	2·10	81+
Dried peas ..	21·00	55·40	1·80	87+
Egg (without shell)	14·80	—	10·50	44—
Golden Syrup ..	—	72·00	—	78—
Honey	—	73·95	—	80—
Margarine ..	1·3		82·70	219—
Milk	3·30	4·50	3·50	18+ Fluid oz.
Milk chocolate	9·39	57·37	29·98	150+
Osborne Biscuits	7·40	79·59	11·10	123+
Potato Chips ..	6·80	46·70	39·80	164—
Quaker Oats (Cooked) ..	1·65	6·24	0·32	10
Roast Beef ..	34·23	—	8·21	59—
Sardines ..	3·83	—	23·75	67—
Tapioca pudding made with milk and eggs ..	3·60	30·00	3·70	46+
Thin Captain Biscuits ..	11·28	80·31	1·68	103+
Van Houtens Chocolate ..	3·90	66·80	27·50	149—
White Bread ..	6·5	51·20	1·06	65—
Wholemeal Bread	6·3	44·80	1·20	58+

Suppose we want to find out how many Calories can be obtained from milk: the calculation can be readily made using Table 3, and our Calorie values for the three different Calorie producing food ingredients.

Thus: Cows Milk (100 c.c.) contains on an average:—

Protein	3·3	grammes.
Sugar	4·5	grammes.
Fat	3·5	grammes.

The Calorie yield to the body from burning 100 c.c. milk would therefore be just over 64½ Calories, calculated as follows:—

3·3 grammes Protein yield 3·3 × 4·1 = 13·53 Calories.
4·5 grammes Sugar yield 4·5 × 4·1 = 18·45 Calories.
3.5 grammes Fat yield 3·5 × 9·3 = 32·55 Calories.

TOTAL .. .. 64·53 Calories.

One fluid ounce of milk is equal to 28·4 c.c. and would have an energy value of 18·33 Calories. A tumbler holds 10 fluid ounces (½ pint) so a glass of milk gives us 183 Calories, and a grown man would have to drink more than 8 pints a day if he depended on this food only for sufficient energy producing food.

If the composition of a food in terms of protein, fat and carbohydrate is known, the Calorie value of any weight of it can always be calculated, but it simplifies the determination of the energy value of a diet if the Calorie value of the individual foods in it can be read directly. Table 3 gives the Calorie-value per ounce of each food. We do not, however, think of our food at each meal in terms of weight, but in terms of homely measures such as slices, cupfuls, spoonfuls and lumps. Table 4 gives for each of a number of foods both the weight and the homely measure which will yield 100 Calories. Using this table it is easy and quick to calculate roughly the energy value of any meal. Making use of Table 4 and Table 2 one could calculate the Calorie value of each meal for several days and find out whether one's daily intake of Calories about balanced one's probable daily Calorie expenditure according to age.

TABLE 4

100 CALORIE PORTIONS

Food.	*Amount yielding* 100 *Calories.*
Apple (raw)	2 small ones.
Banana (skinned)	1 large one.
Beef (roast)	Slice cut fairly thin and large enough to cover a teaplate.
Beetroot (cooked)	Two small ones.
Boiled Cod (boned)	Teacupful of flaked fish.
Boiled Potatoes	1½ medium sized ones.
Butter	Level tablespoonful.
Cane Sugar	6 lumps.
Cheese (American)	2 cubic inches (2 in. × 1 in. × 1 in.)
Dried Dates (stoned)	5
Dried Figs	2 small ones.
Dried Prunes (stoned)	3
Dried Currants	1½ level tablespoonful.
Dried Raisins (stoned)	¼ teacupful.
Egg (without shell)	1½
Golden Syrup	1 level tablespoonful.
Honey	1 level tablespoonful.
Macaroni (dried 1 inch pieces)	⅓ teacupful.
Margarine	Level tablespoonful.
Milk	Full teacup.
Osborne Biscuits	3.
Sardines	2½ fair sized ones.
White Bread	½ inch thick slice of *tin* loaf.

As a rule, an ordinary diet is quite adequate in its energy giving powers; but one should always make a Calorie value determination when judging a diet; and calculations of this sort are most useful when one is criticising the diets of people who have very little money to spend, or when the feeding of groups of people, such as soldiers, hospital patients and school children is being considered.

3. *Quantity and quality of protein.*

Breakdown of body protoplasm and excretion of urea and other nitrogen compounds continues even during starvation. The amount of nitrogen in a protein forms approximately one-sixth of its weight; so that if we multiply the weight of nitrogen excreted by six we know what weight of body protein has been destroyed.

In starvation, the nitrogen loss in an adult corresponds to about 18 grammes of protein, and one would expect that if 18 grammes of protein were given as food that there would be a balance between the intake and loss of nitrogen. Actually this is not the case: the nitrogen loss increases, so that there is still an adverse balance. By increasing the food protein a balance is eventually obtained: about 50 grammes of protein per day is required to bring about such an equilibrium. Evidently protein food stimulates the activity of tissue cells; and this can only be caught up by increasing food protein. If fat and carbohydrates are taken together with the protein, the level at which a nitrogen balance can be obtained is lower—so that on a mixed diet less than 50 grammes per day of food protein will keep the individual in nitrogenous equilibrium.

In Southern Italy the poorest peasants live on cornmeal, green stuff and olive oil, and have no milk, cheese or eggs. The only meat they have is fat pork which they get three or four times a year. These people certainly take less than 50 grammes of protein daily; as also do many Indian natives, who (except for the taking of a little milk) are strict vegetarians.

Among most Europeans and the inhabitants of the United States and Canada the daily protein ration usually amounts to about 100 grammes, and there is no danger of there being an adverse nitrogen balance.

Many people have from time to time objected to this apparent extravagant consumption of protein—maintaining that since excess is excreted, to eat much more than sufficient to maintain nitrogen balance is unsatisfactory. Such an apparent extravagance can be justified if we consider the second way in which the adequacy of the protein constituents of a diet should be judged. The particular essential amino acids are not plentifully supplied in protein as a rule and are certainly lacking in many vegetable proteins; and in order to ensure a sufficiency of the different amino acids we eat a large quantity of various proteins. The excess protein in fact provides that margin of safety for a sufficiency of essential amino acids. If care is taken to include in the diet about one ounce of A1 protein—such as is provided by the proteins of eggs, milk and meat—the remaining proteins can be those in vegetables; and probably a total quantity less than the 3½ ounces (100 grammes) normally consumed would be adequate.

Thus in judging the diet from the point of view of its protein, one must see firstly that it is sufficient in amount to make up for daily nitrogen loss; and secondly that the quality of the protein is such that there is no lack of the essential amino acids. Because animal protein food is expensive, this latter point is of real practical importance and it is in this respect that a diet is most likely to be at fault.

4. *Accessory Food Factors.*

The publication in 1912 by Professor Gowland Hopkins of the results of his rat-feeding experiments greatly interested scientists concerned with problems of nutrition, and other feeding experiments were started immediately in different laboratories all over the world. Lister's discovery that diseases could be produced by micro-organisms had filled everyone's mind with the idea of disease as the result of something harmful coming in to the body and there was a tendency to forget that harm might also result from the lack of something. It came therefore almost as a new idea that danger could result from food, not because it introduced something harmful, but because it was lacking in some essential constituent. In the light of this knowledge, it soon became clear that several diseases, the cause of which had up to then been a mystery, could be classed as *deficiency diseases* and were due to a lack of vitamins in the diet.

Fortunately the discovery of the vitamins occurred a few years before the beginning of the Great War. The war conditions turned nearly the whole of the civilised world into a huge feeding experiment, and the knowledge that vitamins are so vitally important emphasised the danger that might result from restricted diets. The effects produced by the curious food substitutes and by unusual limitations of diet also provided much useful information about accessory food factors.

Most of the work that has been done up to the present has been concerned with the problem of finding out how many important vitamins there are; in what foods these are contained; and how cooking, preserving and storing foods affect the vitamins. We now know that for health and growth human beings require at least four different vitamins. Two of these are chiefly associated with the fatty food of the diet, and the other two with non-fatty food. Since the chemical nature of each vitamin was not known, each accessory food factor was named according to a letter of the alphabet or was given a name that would indicate the particular disease against which the vitamin provided protection.

Accessory Food Factors associated with Fats.

A. vitamin (Anti-infective or anti-xerophthalmic vitamin).
D. vitamin (Anti-rachitic vitamin).

One can say generally that small quantities of all vitamins are necessary for healthy growth, but probably the A. vitamin is particularly important in this respect. It also appears to have a definite effect upon the cells lining the air passages and the alimentary canal, and upon epithelial surfaces in general ; enabling the cells to resist infection. For this reason the A. vitamin is now often called the anti-infective vitamin. It is moderately stable to heat, but prolonged exposure to air or oxygen at all temperatures will render it inactive. This vitamin is formed in leaves of green vegetables, in grass and in vegetables and fruits containing a yellow pigment carotin ; and when these substances are eaten by animals some of the vitamin is stored in the fat of the body. We therefore get our vitamin A. from such vegetable sources and from the fat of the various animal foods we eat. The milk of cows fed on grass, as in the summer, is rich in the A. factor ; but unless the cows are specially fed on vitamin A. foods in winter, the winter milk of stall-fed cows is likely to be deficient in vitamin A. The animal body can store this vitamin in the liver, and one of the richest sources of the A. factor is the oil obtained from the livers of fishes, such as cod or halibut. Strange as it may seem even in fishes the vitamin originally comes from plants. So rich is cod liver oil in the A. factor that one small drop a day is sufficient to keep a rat in good health; and the oil from halibut liver is even richer than cod liver oil in the A. factor.

Milk which has been skimmed or separated loses most of its fat, and so also its A. vitamin. Some years ago children in certain parts of Denmark developed serious eye infections, which caused inflammation and even blindness. These particular children were being given only skimmed or separated milk and vegetable margarines instead of whole milk and butter. It was found that the condition improved when whole milk and cod liver oil were added to the diet; and there is little doubt that the infection was due to the low resistance of the cells of the eye brought about by the lack of A. vitamin in the children's diet.

Skimmed or separated milk provides both sugar and A1 protein in good proportions and therefore has a definite use as a food, but it must not be relied upon as a source of A. vitamin. Margarines are also excellent fat foods, but unless specially prepared supply little or no A. factor. Some firms now manufacture margarines to which the fat soluble vitamins have been added and such margarines are quite satisfactory substitutes for butter.

Accessory Food Factor D., which is the other vitamin associated with fats, is less widely distributed in fatty food than is vitamin A.; but it is less readily destroyed by heat and oxidation, and it can also be made from a forerunner in the animal body in the presence of sunlight.

When there is not enough vitamin D. there is inadequate development of growing bones and teeth, and the condition of rickets may be produced—hence the name *anti-rachitic vitamin*. Rickets may be prevented or cured in children by providing food, such as cod liver oil or halibut liver oil, rich in the D. vitamin; or by exposing the skin of the body to sunlight or to the rays of 'sunlight lamps', or by a combination of the two treatments. The D. vitamin can be formed in a fatty food originally poor in that substance by exposing the food to ultra-violet light (artificial sunlight irradiation) and various preparations of this type, rich in vitamin D., can now be purchased.

There is considerable evidence that a diet overloaded with starchy food hinders the proper hardening of growing bones and teeth, even in the presence of some vitamin D., so that rickets may appear in children who are having plenty of food, but whose diet is over-rich in carbohydrate. In cities where smoky fogs prevent natural sunlight from exerting its protective action against rickets, special care must be taken either to provide the D. factor in the diet, or else to form it in the body by ultra-violet light treatment from artificial sunlight lamps.

After the Great War the conditions were such in Vienna that many babies suffered from severe rickets. Dr. Harriette Chick of the Lister Institute in London was asked to go to Vienna to deal with the problem. By a combination of light treatment, and cod liver oil dosing she was able to effect wonderful cures among the babies. The accompanying illustration is a photograph of one of these rachitic babies before and after cod liver oil and sunlight treatment.

The second set of teeth are already growing in the tooth sockets during infancy while the first or milk teeth are being used ; and a diet that contains too little of the D. factor in early childhood may seriously hurt the quality of the so-called permanent teeth, even though these are not cut till years later.

Accessory Food Factors associated with Non-Fatty Foods.

Vitamin B. (anti-neuritic vitamin B_1 and anti-dermatitis vitamin B_2).

Vitamin C. (anti-scorbutic vitamin).

Vitamin B.

Probably several vitamins form the so-called B. Factor and it is now usual to speak of the Vitamin B. Complex to indicate this fact. Usually all the different B. factors occur together in a food, and therefore it is not important here to consider their individual properties.

Acute deficiency of the B. complex may lead to serious conditions, in which the nerves and muscles or the skin may be affected. Such an excessive lack of the B. vitamins is rare in this country ; but too little of the B. complex may perhaps be responsible for general ill-health of the nervous system, or unhealthy skin conditions, for poor appetite and an unhealthy condition of the alimentary canal. The B. vitamins are contained in cereals, but chiefly in the germ and in the layer just under the pericarp, so that when wheat is milled or rice is polished the grain is largely deprived of its value as a source of B. factors. Bread made from either white or wholemeal flour is an excellent source of starch and contains protein but since wholemeal flour still contains the germ and husk of the original grain, it provides the vitamin B. complex in addition to carbohydrate and protein.

Vegetables, lean of meat, ox liver and egg yolk are good sources of the B. complex. Yeast and yeast-preparations, such as Marmite are rich in the B. factors. The heat necessary for cooking does not as a rule seriously affect the B. complex, but in boiling and stewing the vitamins may diffuse into the cooking water.

Vitamin C.

The most unstable vitamin and the one which suffers most from heating, canning, storage and drying of the fresh food is the anti-scorbutic or C. factor. For this reason the condition of scurvy, which we now know to be caused by lack of vitamin C., has long been the scourge of sailors, explorers and any groups of people cut off from supplies of fresh meat, fruit and vegetables.

In 1734, Bachstrom wrote as follows*:—

> " From want of proper attention to the history of scurvy, its causes have been generally, though wrongfully, supposed to be cold in northern climates, sea-air, the use of salt meats, etc., whereas this evil is solely owing to a total abstinence from fresh vegetables, food and greens; which is alone the true primary cause of the disease. And where persons, either through neglect or necessity, do refrain for a considerable time from eating the fresh fruits of the earth, and greens, no age, no climate or soil are exempted from its attack. Other sedentary causes may likewise concur, but recent vegetables are found alone effectual to preserve the body from this malady; and most speedily to cure it, even in a few days, when the case is not rendered desperate by the patients being dropsical or consumptive."
>
> [translation given by Lind (1757. p. 394).]

The practice of giving orange juice to babies fed on dried or condensed milk aims at supplying the C. vitamin which may be largely destroyed by the treatment which the fresh milk undergoes in drying and condensing.

A fifth accessory food factor, vitamin E. has now been discovered, but there is as yet little evidence that it is required in the diet of human beings.

The discovery of the action and the distribution of the different accessory food factors is certainly one of the adventures of science, and our knowledge concerning them has considerably modified our ideas of what are good, bad and indifferent diets.

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* From Medical Research Council Special Report. Series 167. Vitamins: A Survey of Present Knowledge.

Table 5 shows the vitamin content of some ordinary foods.

* TABLE 5.

O Signifies vitamin has been tested for and not found.
+ ,, that the material contains the vitamin.
++ ,, that the material is a good source of the vitamin.
+++ ,, that the material is a rich source of the vitamin.

FOOD.	A	D	B	C
Cows' Milk (Fresh)	+ (varies)	O to + (varies)	+	+
Cows' Milk (Pasteurised)	+ (varies)	..	+	+
Cows' Milk (Sterilised)	+ (varies)	..	+	O to +
Cows' Milk (Dried)	++ (varies)	O to ++ (varies)	++	O to +
Butter	+ to ++	+ to ++	..	O
Cheese (American)	++	..	O to +	+
Hen's Egg	++	++	+ to ++	..
White Bread	O	..	+	O
Wholemeal Bread	+	..	++	O
Margarine (Vegetable)	O	..	O	O
Potato (Cooked)	+	..	..	+ to ++
Cabbage (Cooked)	+	..	..	+
Lettuce (Green)	++	..	+ to ++	+++
Tomato (Ripe)	++	..	++	+++
Tomato (Canned)	++	..	++	++to+++
Lemon (Juice)	+	..	+	+++
Banana	+ to ++	Low	+	++
Beef	..	..	++	O to +
Beef Fat	++	+	O	..
Mutton	..	..	++	O to +
Mutton Fat	+	..	O	O
Cocoa	+	+ to ++	..	..
Marmite	..	..	+++	O

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* Compiled from Medical Research Council Report, 167.

5. *Inorganic Constituents.*

By the inorganic constituents we mean the elements such as sulphur, iron, iodine, calcium and phosphorus which may form part of the compounds making up a food. It is true that the average diet is probably adequate in its content of such elements, but it is as well to keep an eye on a diet from this point of view and to find out for certain that each is included.

Table 6 gives a list of certain foods which are useful sources of these elements, and if such foods form part of the diet one need not fear a deficiency of inorganic constituents.

TABLE 6.

Foods especially useful in supplying certain inorganic constituents.

Iron	In Liver, Kidney, Beef. Egg yolk. Oatmeal, wholemeal flour, dried peas. Green vegetables, especially spinach. Raisins.
Calcium	In Cheese, Milk. Eggs, Veal. Green vegetables. Nuts.
Phosphorus	In Egg, especially egg yolk. Mutton, beef, fish roes, liver, brains. Cheese, Milk. Haricots. Wheat-germ.
Iodine	In Fish. Some water plants (Watercress).

6. *Appetising and Digestible Food.*

The ability to digest and absorb ordinary food is not usually a matter for consideration by a young healthy person. Provided the food is appetising and the ordinary laws of health are not disregarded, indigestion is unlikely to worry children or young people. Indigestion is due, as a rule, not to any unsatisfactory quality inherent in the food but to the fact that it has not been adequately chewed or that one has been too active directly after a meal. Poisons from bad teeth are sometimes the cause of indigestion.

There are curious individual peculiarities in respect of certain foods, and something which may be readily digested by every other member of a household, may quite seriously upset one person. In fact it is true that 'one man's meat may be another man's poison', and the old fashioned idea that everyone can and should eat every kind of food is fortunately not now universally believed. In general fatty foods are the ones most liable to produce symptoms of indigestion.

7. *Roughage: Chewing.*

The slow digestion, or lack of digestion, of a certain proportion of the food is useful, since the bulk stimulates the muscular walls of the intestine and encourages peristalsis. Food that acts in this way is said to provide 'roughage,' and this is most usually contained in vegetable foods. Vegetables provide cellulose, the breaking-up of which is not carried out by the enzymes of the digestive juices but only by intestinal bacteria. The husks of cereals (wholemeal bread) and the skins of dried fruits (prunes), because they contain a good deal of cellulose, may thus serve a useful purpose as natural laxatives.

The importance of chewing is in part that there should be thorough mixing of the saliva with the food, but hard food which necessitates vigorous biting has yet another value. By biting well the jaws are exercised and their blood supply is increased and at the same time also the blood supply to the teeth.

A tooth is a specialised structure developing in the jaw, and slowly pushing its way through the gum. Teeth are required for the adequate breaking-up of solid food in the mouth. Each tooth (*Fig.* 24) has a hard cap (enamel) above the gum, and this protects softer underlying living material (dentine), which forms the main mass of the tooth. The dentine is nourished from a hollow in the centre of the tooth into which pass nerve fibres and blood vessels; and the growth and healthiness of the tooth is dependent upon a good flow of blood to this *pulp cavity*, as the hollow centre is called. The dentine is protected from the action of decay by the hard enamel, and, in the main, good teeth are those which have properly hardened enamel of adequate thickness. The conditions necessary for the formation of healthy bones and teeth are very much the same—they must be supplied during growth by calcium and phosphorus, which are their chief inorganic constituents.

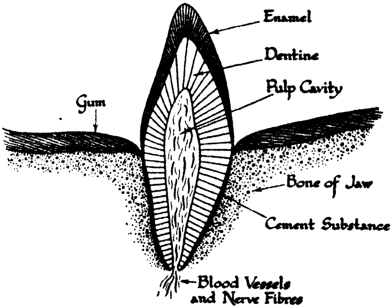

Fig. 24: Section through a Tooth.

Vitamin D. must be present in the body to enable the calcium and phosphorus to be so used.

The attack upon enamel and dentine, which leads to decay (caries) comes from outside, that is to say, from the mouth. It is therefore wise to keep the mouth cleaned of food particles, whose presence may encourage caries. Brushing all round and between both upper and lower teeth removes pieces of food that may have lodged in the mouth ; and biting hard fruit, such as an apple, is a good way of exercising the jaw and also of removing bits of soft food caught between the teeth. When one is asleep, and not moving tongue or teeth and no saliva is washing out the mouth, there is much more chance for organisms to grow ; and therefore the most important moment for cleaning the teeth is just before getting into bed. After that no other food, except an apple should be eaten.

Teeth are growing in the jaw for a long time before they are cut, in fact even before the baby is born. A mother should take special care about her food during the months before her baby is born and during the time the baby is being fed on the milk she provides. This is important not only for her own sake but for that of her baby whose teeth will not be strong and healthy unless they are provided with the right teeth-forming constituents during those months. The food and health of a child affect not only the first teeth (milk teeth) but also the permanent teeth when they are cut.

Bad or inadequate feeding or a serious illness may stop the growth of the teeth before they are actually cut, and this will show itself as a line in the structure of the tooth later on.

8. *Injurious food.*

As a rule food does not contain anything harmful, but carelessness in its transport, storage, cleaning and preparation may cause it to become injurious to health. Health may be affected by :—

a. *Disease germs in food.*
Milk contains the suitable food constituents for the young growing animal and is thus also a suitable food for a great variety of micro-organisms which grow in it quickly. The present day demand for ‘clean milk’ is a wise and important step in the direction of good health. Dust and flies are often the means by which food becomes contaminated and we are still far too tolerant of the way in which much of the food we buy is exposed.

b. *Ptomaine poisoning from food.*
Poisoning may result from eating foods that have been kept too long. Chemical changes of decomposition take place, and the poisons are sometimes so violent that the smell of the food is sufficient to make one seriously ill. On the other hand, sometimes the change is apparently so slight that there is neither bad smell nor taste and one does not know that poisoning has occurred until severe sickness and diarrhœa starts. Meat-foods kept in warm cupboards or in unventilated places are liable to develop ptomaines. Meat-pies, sausages and similar foods are likely to be unsafe in warm weather.

9. *Climate, age and occupation.*

Climate. Most of us make changes in the amount and kind of food we eat according to whether it is cold or warm weather. We eat more food and have hot food in cold weather and increase the proportion of the Calorie yielding constituents. Correspondingly, we cut down the amounts in the summer and satisfy appetite with food such as salads and fruit, which have low Calorie values. The high fat food intake of Esquimaux is an excellent example of the effect of climate on diet.

Age. Table 4 shows that children require more Calories than one might expect for their weight and height. A baby has a relatively greater heat loss from the surface of its body and this loss must be made good by a large Calorie intake. Older children are very active and so they too, require a big income of energy units. Children are growing animals, and require a considerable quantity of body building material in food. The large appetite of boys and girls is the natural result of their activity and growth. All the food ingredients necessary for formation of bone, teeth and blood hæmoglobin are particularly necessary during childhood; and any boy or girl who realises this can easily make a note of the meals eaten during a week and find out whether the foods eaten have included the necessary growth constituents.

Occupation. The daily intake of Calories, unless one is to gain or lose weight, should balance one's daily energy expenditure.

People who live in towns and who work in offices have a far smaller Calorie expenditure than those who lead active lives; and the diets should be correspondingly different.

For the sedentary worker an easily digested diet, not overloaded with carbohydrate is best; whereas a manual worker can obtain the necessary increase of Calories by an increase of starchy foods and will suffer no harm.

The following table of hourly Calorie expenditures compiled from figures given in Lusk's *Science of*

Nutrition shows how occupation affects energy-production.

Man	At Rest	53	Calories per hour.
,,	Reading	86	,, ,, ,,
,,	Playing Violin ..	99	,, ,, ,,
,,	Waltzing	280	,, ,, ,,
,,	Carpentering ..	217	,, ,, ,,
,,	Chiselling Stone ..	353	,, ,, ,,
,,	Running 5·3 miles	550	,, ,, ,,
,,	Swimming 2 miles	624	,, ,, ,,

Included in the normal diet are certain other substances which have not yet been mentioned. Pepper, mustard and spices make the food tasty and may help in encouraging a good flow of appetite-juice; but a normal healthy child usually has a good appetite and does not need to have highly-spiced and highly-flavoured food. Tea and coffee are helpful in slightly stimulating the nervous system of a tired grown-up, but except for the milk taken in the tea and coffee neither drink is in any sense a food. Tea may actually be harmful if it is allowed to infuse for a long time. Tea which has 'stood' contains a bitter substance (tannin). Tannin can also be extracted from bark and is used in the making of leather because it hardens the protein of the skins. Strong infused tea taken with food is likely to harden food protein and delay protein digestion.

CHAPTER XVI

FOOD IN THE HOME

Cost and Cooking of Food.

THE cost of our food is naturally an important problem ; and though it is true that, generally speaking, the probability of the diet being satisfactory is increased when more money is spent, it is equally true that there are many expensive diets that are grossly unsatisfactory and there are many adequate cheap foods. Diet is largely a matter of common sense ; and this commodity has no direct connection with money. The chief difficulty in planning a diet on a small income is to provide sufficient to satisfy appetite and to supply so many different constituents and at the same time not to over load the diet with the always-cheap starchy foods. Valuable vitamin carriers, such as fresh fruit and vegetables, eggs and milk, are expensive and neither animal proteins nor animal fat are cheap as a rule.

It can be seen how much careful thought and planning there must be on the part of the mother of a family of growing children, if she is to provide, not only enough food but also food that is appetising and gives the various proteins, inorganic constituents, and vitamins so essential for growth.

Starchy foods are cheap and filling and as most of us like bread, potatoes, dried peas and lentils, suet puddings and home-baked cakes, the necessary Calories can, in the main, be provided in this type of food, but it is getting enough A1 proteins, vitamins and inorganic constituents that is going to present the real difficulty.

Fortunately there are some foods which are relatively inexpensive and will help to provide useful appetising additions to the main hunger-satisfying carbohydrate foods. Suet and dripping are cheap fats which provide the A. vitamin. Butter, although it is more expensive than the cheapest margarines, provides the fat-soluble vitamins which are lacking in any but the special A. and D. vitamin-carrying margarines. Milk is not a cheap food if we judge it only by its Calorie value, but money spent on milk for children really gives a good return because milk provides A1 protein, calcium, phosphorus and fat-soluble vitamins.

The proteins and fat of milk together with its organic constituents and vitamins can be got in a concentrated form in cheese, and as cheese is both tasty and cheap it is a really valuable help in making a starchy diet more adequate. Butcher's meat is an expensive item, and the so-called 'good cuts' are good only in that they are often less bony and gristly. The actual food value of the meat as a source of protein, inorganic constituents and vitamins is as good in a cheap cut (say calve's head, skirt or shin of beef, or scrag end of neck of mutton) as that of the expensive meat of beef-steak or best end of the neck. Fish is generally considered expensive—but the various forms of the herring (fresh herring and kippered) and other cheap fish have an excellent value as a source of protein and vitamins. The difficulty that used to be experienced in getting supplies of fruit and vegetables in winter has now practically disappeared, so that all the year round cheap apples or oranges are available. In this connection it is worth remembering that for food purposes tomatoes are equivalent to fruits and even when cooked or tinned are excellent sources of vitamins. Foods made of wholemeal and standard flour are appetising and are certainly better than those made of very purified white flour, both as a source of B. vitamins and of roughage. To make starchy food tasty marmite is helpful and is another excellent way of providing the B. vitamins.

TABLE 7.

FOOD.	COST OF 1 LB. AS BOUGHT.	CALORIES FROM 1 LB. OF EDIBLE PART OF FOOD.	
		RAW.	COOKED.
Leg of beef for stewing (imported).	6d.	—	896
Cod for boiling ..	10d.	—	480
Eel	8d.	—	1024
Butter.. .. .. Margarine	10d. 4d.	3577 3504	— —
Cheese (Empire) ..	7d.	1303	—
White Bread.. ..	1½d.	1040	—
Cooking Apples ..	2d.	238	—
Old Potatoes.. ..	1d.	—	400
Granulated Sugar ..	2½d.	1740	—
Eggs	1d. each	44 Calories each	—
Milk	1 pint 3½d.	366 Calories per pint	

Table 7 gives the cost and Calorie value of a number of common foods and illustrates the fact that the value of a food is not necessarily greater if the price is higher. The prices given, are only approximate since nearly all vary with season and district.

Making use of these suggestions and finding out how much money is usually spent on food at home each week, one might try to plan a week's meals for the family using only this amount of money. The amount of each food that is bought and its cost must be written down; and having made the 'food budget' in this way, one should criticise it on all the nine points and see whether one has succeeded in providing satisfactory meals for every member of the family.

Tied-up with the problem of the cost of food is the question of its preparation and of its storage, and this must be kept in mind when making the plan. In considering the preparation of food one should note whether it is fresh, dried or tinned. One may take it as a general rule that fresh food provides vitamins and that a food which has been dried or tinned has had its vitamin value reduced.

Cooking serves a number of useful purposes, and one must use common sense in deciding whether or not any particular food should be cooked, since the good resulting from cooking often outweighs the harm done to it by heating it.

Cooking does good because:—

(1) It makes starchy food digestible. Heating splits the cellulose envelopes of starch granules and so allows the digestive enzymes to reach the starch.

(2) It loosens the fibres of the meat by dissolving and softening the connective tissue between the fibres. This is particularly true of boiling. Heating meat coagulates the muscle proteins

in exactly the same way that the proteins in egg are solidified when an egg is hard boiled. If meat is chopped into pieces and put into cold water some of the juices of the meat pass out into the water before the outside fibres are coagulated and a rich, tasty gravy is produced. On the other hand, if the meat is put straight into boiling water the proteins on the outside of the meat are hardened quickly and most of the juices remain in the meat.

(3) It produces tasty flavours and makes the food more appetising. This is especially true of baking and frying. Changes produced in fat on heating may irritate the stomach, and so make hot food cooked in this way indigestible.

(4) It destroys harmful micro-organisms and parasites which may be in the fresh food.

Against these advantages must be set the fact that heating tends to reduce the activity of the accessory food factors and this is particularly serious in the case of the C. vitamin.

The Storage and Keeping of Food.

In the home the problem is mainly a battle against micro-organisms that may get into the food by means of dust in the air or because flies have settled on the food. Many foods may arrive in the house already contaminated to some extent, but no harm may be done and food will not spoil, so long as the organisms are prevented from growing quickly. Keeping all food cool, and dry food from getting wet, will as a rule prevent rapid growth of germs. Acid foods go mouldy, sugary ones ferment and protein foods putrefy. Milk is one of the most difficult foods to keep because not only is it wet, but in it are all three carbon containing food constituents and so it provides the right kind of nourishment for so many types of microorganisms.

Where there is a cool cellar the problem of keeping food is not difficult, but in most homes the storage-place for food is either a cupboard or a shelf in the kitchen or living-room, and then trouble begins! The first thing to do is to be sure that dust and flies cannot get to the food and that the food is placed in clean jugs or on clean plates. Secondly, one must see that the food is kept in as airy and as cool a place as possible. Thirdly, in the case of milk, in hot weather it is as well to *boil* it directly it comes into the home. Most milk is now pasteurised and delivered in sealed bottles. In pasteurising the milk is heated to some temperature lower than boiling point—usually 165° F. This destroys all the organisms which turn milk sour and also many of the germs of disease that are likely to be in the milk. After heating, the milk is cooled rapidly.

During the summer germs grow quickly in milk and it is probably wiser to boil it as soon as it is delivered. Boiling may reduce the vitamin content but it also reduces the risk of infecting children with germs likely to produce diarrhœa and sickness. In the winter when there is less dust about and milk can be kept cool easily, pasteurisation is probably sufficient to render the milk safe, and it will keep for at least a day or two after the bottle is unsealed.

How can food be kept cool and in an airy place? This is where common sense comes in. There may be a shelf or cupboard that will do because it is near the window and away from the stove, and provided the food is covered it will remain in good condition. One may be able to make a simple food-safe with a wooden box, having a door of perforated zinc and this box could be hung close to or just outside the window: or a cheap meat- or butter-container that will keep out the flies can be bought for a few pence or can be made at home.

When one thinks of the enormous variety of perishable foods available the whole year round in this country, one realises how marvellously the problem of feeding the community has been solved during this century. In the so-called ' good old days ' the methods used for preserving foods were of three kinds. Food was dried, salted or smoked, these treatments being used alone or together. Such methods provide us with kippers, bacon, milk- and egg-powders, and dried fruits, such as dates and sultanas. Alternatively fresh foods may be heated to destroy micro-organisms and the material while hot sealed from the air. This is the method used in canning and bottling. Sometimes the growth of micro-organisms was prevented by the addition of chemicals.

Such methods as the first two, are likely to make the food deficient in vitamins and while adequately preserving the food, produce something which has not the same flavour as the fresh food. The last method has the obvious objection that since the preservative is harmful to the micro-organisms it may also be harmful to the human consumer. These methods depend upon the fact that micro-organisms are destroyed when heated or when chemicals are added to them or become inactive when their surroundings are dry. We make use of these same facts in fighting germs elsewhere. Antiseptics are substances which are used to destroy germs, but sometimes are only strong enough to slow down their growth. In an operating theatre instruments are sterilized by heat or chemicals and are absolutely aseptic. After an infectious illness the patient's room is fumigated by chemicals to destroy the germs and the bedding and clothes are disinfected by heat at the disinfection station.

The drama of modern food-preservation and food-transport has been, in the main, built upon the application of the scientific fact that the growth of micro-organisms is stopped by low temperatures. Refrigeration (freezing or cooling) now plays its part in all rail- and ship-transport of fresh food ; and at the docks and in the wholesale warehouses there are huge refrigerating-rooms, where the food is stored until it can be released in smaller quantities for purchase by the retailer for consumption.

That anyone in Great Britain can still suffer from a deficiency disease due to lack of fresh food is something of an indictment of our intelligence and of our sense of citizenship.

CHAPTER XVII

THE KIDNEYS AND THE SKIN

IN the general processes of metabolism the body makes a number of substances which are not wanted or are formed in excess of the needs of the body. The process of getting rid of these substances is spoken of as *excretion*. The body excretes by four different paths.

The lower end of the large intestine, as has already been seen, finally contains a mass of material (fæces) which is eliminated. Bacteria form a large part of the fæces—even up to half the weight of fæces may be formed of micro-organisms. In addition fæces contain worn-out cells from the lining of the intestines, unwanted ingredients from the food and materials from the digestive juices. This mass collects in the rectum and the emptying of the bowel is a process of excretion.

The lungs, besides providing us with a means of acquiring oxygen, also provide the path by which excess of carbon dioxide is sent out from the blood. Carbon dioxide in the blood serves many useful functions but since the cells are continually oxidising carbon compounds, more carbon dioxide is made than is needed, and is got rid of through the lungs. The lungs may therefore be considered partly as organs of excretion.

In the sweat there are traces of unwanted materials dissolved in the water and this fluid together with the oily secretions of the glands emptying into the hair-follicles, makes the skin also an organ of excretion, though not a very important one.

The kidneys are the most active of the body's excretory organs. Their great function is indeed to keep the blood at a very steady composition which is absolutely necessary if the cells of the body are to be kept working.

The Kidneys.

The two *kidneys* lie one on either side of the backbone, against the muscles of the back and are imbedded in a good deal of fat. From each kidney passes a narrow tube, the *ureter*, which opens into the *bladder*. The lower end of the bladder opens by another tube, the *urethra*, to the exterior. The *urine* made by each kidney passes along the ureter to the bladder where it collects and slowly fills the bladder and stretches it. The neck of the bladder is normally kept closed by several rings of muscle. In a newly born baby the emptying of the bladder is a purely reflex action, and occurs when the stretching of the bladder produces a sense of discomfort. As a child grows older this reflex comes under control of the will and the passing of water (*micturition*) only occurs voluntarily. In a healthy person this control becomes a strong habit and even when there is severe discomfort as the bladder becomes more distended, the emptying is restrained until a suitable occasion arises. The stimulus provided by the bladder as it fills is a strong one and when a child is not in good health or is worried and anxious the control may break down, especially during sleep, and micturition once again becomes a purely reflex action.

Harm may result from over-distension of the bladder and the discomfort produced by a distended bladder should be recognised as a sign that micturition ought to take place as soon as possible. On the Continent a sensible and frank attitude towards this normal and necessary process is generally adopted, and boys and girls accept without embarrassment or comment the fact that when they are together for any length of time, as for example during a day's hiking or cycling each must periodically retire, whether in a town or out in the open country.

The kidney itself is one of the most marvellously constructed organs in the whole body. It has a quite unique arrangement of its tiny blood vessels, which bring the blood into close contact with the closed ends and the length of thousands of minute tubules, the other ends of which open into the expanded end of the ureter. The general arrangement of a sheep's kidney is very like that of the human kidney. In a breakfast kidney one can see the expanded end of the ureter inside it and the streaky effect produced by the tubules as groups of them pass from the outer part towards the ureter.

As the blood circulates through the kidney capillaries, water and various dissolved substances pass through the very thin walls of the tubules and thus the urine is formed. The urine is a yellow liquid and the intensity of its colour varies with the amount of water in the urine. After exercise, when much water has been got rid of by the skin, less is passed by the kidneys and the urine is deep yellow. On the other hand if one drinks a great deal of water a bigger volume of urine is formed and the liquid is pale yellow in colour. Urine contains the urea formed from amino acids during the metabolism of proteins. Urea gradually breaks down forming ammonia and it is this substance that produces the characteristic ammoniacal smell of stale urine. A very small trace of urea is also excreted by the skin in the sweat but even this tiny quantity is sufficient to give an odour to sweat-soaked clothes which have not been washed.

Sweat and urine are liquids containing excreted substances in solution, so that whether or not there is excess water in the body, that vitally important material is continually being removed. It is possible to live for many weeks without taking the other food constituents, as the reserve stores of carbohydrate and fat can provide sufficient energy producing fuel for a long time, but if a person is unable to get liquid to drink death occurs in a few days. Water is constantly being lost by the skin and kidneys and with no compensating water intake the cells of the body are unable to continue their work. Fasting people must always drink water or some other fluid containing water.

A group of students who for an experiment allowed themselves to be deprived of food, found that the irritability and headaches which resulted, disappeared on taking water. Thirst is a useful warning that the water balance of the body is beginning to be upset, and quite often a fretful baby is crying not because it is in pain or in need of food, but because it is uncomfortable through thirst.

After profuse sweating such as occurs in very hot weather or during violent exercise, it is probably wiser to satisfy slowly the thirst caused by the great loss of water, so that the replacement is gradual and no sudden change in blood-volume and blood-composition occurs to disturb the functions of the cells. Miners, who do very hard muscular work in a hot atmosphere, sweat excessively and if they satisfy their thirst with water may suffer from a condition called *miners' cramp*. In this case the amount of water lost from the skin has carried out with it much common salt. It sounds an odd way of relieving thirst, but if these miners drink salt water instead of ordinary water the condition of cramp does not occur, because the proportions of salt and water in the body fluids remain unaltered.

Ordinarily, one loses about four pints of water from the body in the twenty-four hours. The water one drinks, together with the water contained in the solid food and made during metabolism, ought to balance this daily loss. Probably most people do not take enough liquid. We do no harm by taking plenty of water, as the kidneys will get rid of excess. In order to be on the safe side it is probably wise to drink three or four pints of fluid daily. If one keeps an account of the amount of fluid one drinks each day for a week, it is possible to find out whether one really does take as much as three or four pints daily and also whether the amount one wants to drink is altered by changes of outside temperature or by violent exercise. All fluid taken, whether tea, coffee, milk or lemonade as well as plain water must be counted. An ordinary afternoon tea-cup holds about a quarter of a pint and a tumbler or a breakfast-cup about half a pint.

The Skin.

Although from the surface the skin looks to be quite a simple structure, this is not really the case. If one looks at the skin with an ordinary magnifying-glass one can see there are many little pits in it and the meaning of these can be understood when a piece of skin is examined under the microscope. Figure 25 shows that the skin consists of two layers. The top layer (*epidermis*) consists of many rows of cells, of which the top ones are flat and scaly. As the surface of the skin is continually being rubbed, these flat scales get worn off and are replaced by growing cells from the layers below. From the pits in the epidermis pass the tubes of the sweat glands which are imbedded in the lower layer of the skin (the so-called *true skin or dermis*). In the dermis are also the *hair follicles* from which hairs grow out through the epidermis. Opening into the follicles are oil glands (*sebaceous glands*) which manufacture an oily material. Fine muscle fibres are attached to the hairs and in furry animals these fibres contract and make the hairs stand on end. The dermis contains blood capillaries which are particularly numerous round the roots of the hairs and the sweat glands. In the epidermis there may be

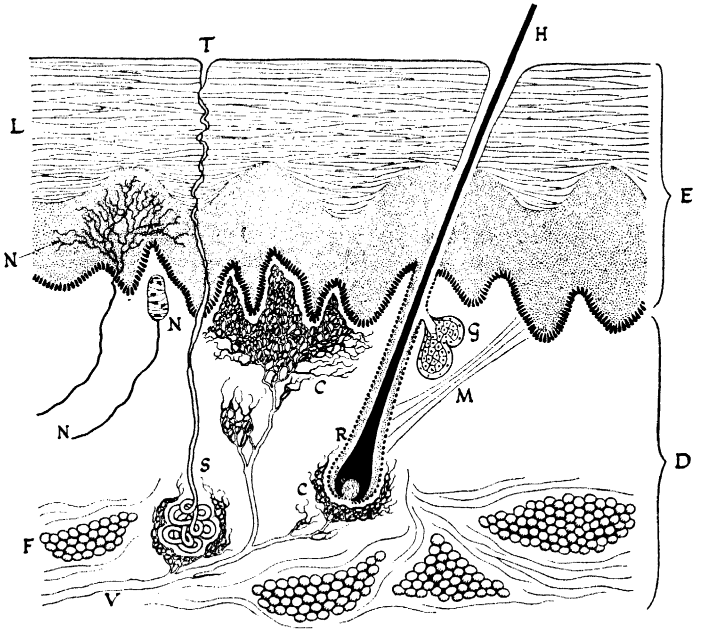

Fig. 25 : Section through the Skin, highly magnified.

C = blood capillaries
D = dermis
E = epidermis
F = fat
G = oil gland
H = hair
L = flat and scaly cells of epidermis
M = muscle
N = nerve fibres and nerve endings
R = hair-follicle
S = sweat gland
T = sweat duct
V = large blood-vessel

fine branching nerve fibres and in the dermis there are nerve fibres to the hair follicles and special nerve endings of touch. In the lower part of the dermis there is fat, which varies in amount in the different parts of the body and in different people.

It is true that the skin is an organ of excretion and that substances leave the body both in the sweat and in the oily material from the sebaceous glands, but both these fluids have other uses and the skin has functions which are much more important than that of excretion.

The *sebum* from the sebaceous glands helps to keep the hairs in good condition and also provides a waterproof coating for the epidermis. One can easily see when one is having a bath how readily water runs off the skin. It is because of the oily coating that no watery fluid can pass between the cells of the epidermis.

The skin is very important, because by it the temperature of the body is regulated. The heat produced in the active cells of the body when they oxidise the carbon containing food supplied to them, warms up the blood and unless that heat were lost at a rate approximately equal to its rate of production the body temperature would rise. Human beings are 'set' to work at a definite body temperature—round about 98·4° F.—and any marked variation from that temperature level upsets the normal activities of the cells. It is therefore necessary if we are to maintain a constant body temperature that there should be good adjustment of heat loss to heat-production, and that the two should be balanced. Regulation might be brought about by control of both heat production and of heat loss, or of one process only. All work done by the cells must produce heat, and this production is not capable of much control. It is true that in cold weather we eat more and so provide more fuel, and also are more energetic and so burn more, but the body balances its heat production and heat loss by the much more sensitive method of regulation of heat-loss. This regulation is mainly brought about by variation in two distinct and different processes going on in the skin. All hot bodies, whether tea-pots, hot-water bottles, or ourselves, must lose heat if their surroundings are cooler than they are. The loss takes place by all the three physical methods of heat-transference. We lose heat by radiation to cooler objects at a distance, without warming the intervening air; by warming the material or air in contact with the body so that heat goes away by conduction; and, as the warmer adjacent air becomes lighter and rises, currents are set up and heat is lost by convection. The skin is always losing some heat by all these methods; and the cooler the surroundings, the more quickly will the heat be lost. Since it is the blood that gets warmed up inside the body by the burning of our 'fuels,' it is the warmed blood coming to the skin which transfers the heat from the active organs to the skin.

If the amount of blood that flushes the skin blood vessels varies, the amount of heat that is lost from the skin correspondingly varies. When the muscles are active the heat production in the body is increased. When the surroundings are warmer (summer weather) and it is less easy for heat loss to occur quickly, the tiny skin vessels get larger, more blood rushes through them (making the skin pink) and more heat can be lost.

Covering the body with clothes cuts down the ease with which heat can get away from the skin and that is why one alters the amount and the material of the clothes according to the outside temperature.

Another and quite different way in which the skin enables the body to regulate loss of heat is by the evaporation of water from the surface of the skin.

Evaporation of water helps to cool the body because heat is required to change a liquid to a vapour; and in the case of the body this latent heat of vaporisation is obtained from the warm skin. The more quickly the vaporisation occurs, the more quickly is heat taken up. If it is very rapid the tiny nerve endings in the skin are stimulated and one is aware of coolness of the skin. The temperature at which either ether or alcohol evaporates is lower than that for water. At ordinary room-temperatures both these liquids evaporate more quickly than water and if a drop of either of these liquids is put on the back of the hand or on the forehead the spot will seem quite cold, as the latent heat of vaporisation is taken away from the skin so quickly. The soothing, cooling effect of eau-de-cologne or lavender-water when one has a headache is partly due to the rapidity with which the alcohol in the liquid evaporates. When the heat production by the body is suddenly increased, as it is during exercise, and when the temperature of the air is raised, the loss of heat must be increased. The body is always losing some water from the skin (*insensible perspiration*), and when heat-loss must be increased, the sweat-glands become active and sweat is poured out so rapidly that it appears as drops of sweat (*sensible perspiration*). Normally, about one pint of water a day is lost from the body by sweat, but on a warm day, when one takes moderate exercise this quantity may easily be increased five times. It was estimated that during a ride in California where the temperature was 45° C. (body temperature 37° C.) a man lost, by sweating, eighteen pints of water from the body.

The rate at which sweat dries will determine to what extent this method of heat loss is useful to the body, and, as the rate of evaporation is dependent upon the amount of moisture in the air, the loss from the body by sweat-evaporation is not very effective in climates in which the air, though warm, is also very moist. Tropical climates, where there is much moisture in the air, are much more difficult to endure than those of places where it is actually hotter but where the air is dry. One finds that in a moist tropical climate the slightest exertion causes excessive sweating and the clothes are wet through even as one changes them, but little or no relief is felt since the liquid evaporates so slowly. On the other hand it is possible in a dry tropical climate to play hard sets of tennis and feel little or no discomfort ; and though, while playing, one may perspire profusely, the clothes remain quite dry since evaporation has been so rapid.

When the air is laden with water vapour heat loss from the body must be brought about by other methods than the evaporation of sweat. Water vapour is a better conductor of heat than is air, and when the air is moist heat will be lost from the body by conduction. Contact with cold objects such as ice or cold water makes one feel cold and probably that is why on a wet day, it may seem colder, in spite of the fact that the thermometer shows there has been no actual fall of temperature.

The loss of heat from the skin should be continually going on steadily and slowly. Anything which causes a too rapid increase in the rate, produces a sense of chill, whereas any condition which greatly reduces the heat loss may give a sense of discomfort and stuffiness.

Another most important function of the skin is that of protection. The epidermis protects the body in various ways. It protects the delicate structures beneath from being harmed by very hot or sharp things. The outer layers may be injured, but, in a healthy person, this part recovers easily. These outer layers also prevent the entrance of germs, which can only get in if the skin is scratched or cut. To destroy any germs that may be in a scratch or cut, it is wise to put iodine or some other germ destroying substance on the skin at this point at once.

The tiny nerve endings between the cells of the epidermis and in the dermis give one information about changing conditions near the skin. If that change is something painful or injurious one can then move away. In human beings the hairs are useful as sense-organs, and give one information about objects just going to touch the skin. In furry animals the hairs serve the same purpose as clothes serve us, and prevent rapid loss of body-heat.

CHAPTER XVIII

CLOTHING—THE CARE OF THE SKIN—SUNLIGHT, AIR AND VENTILATION—CARE OF THE BOWELS

Clothes.

CLOTHES protect the body and prevent excessive loss of heat from the skin. Clothing materials are poor conductors of heat and because they imprison some air between the fibres, and between the garments, the continuous loss of heat is slow. Clothing takes up perspiration and retards the rate of its evaporation, thus again cutting down heat loss.

The value of the different materials commonly used for clothing depends upon the particular kind of garment under consideration. As one would expect, wool which is really sheep's hair, possesses the same properties, when used for clothes, which makes the fleece useful to the sheep. It is a poor conductor of heat, entangles a good deal of air and holds perspiration in such a way that it does not evaporate quickly. In this way it keeps the sheep from losing heat too quickly, and equally is useful as a clothing material to be worn next to the skin. Woollen sweaters to pull on after violent exercise when the skin is flushed and much sweat has been poured out, are especially useful in preventing very rapid heat loss and the sensation of 'chill.' The slight roughness of the surface of woollen materials for underclothing is sometimes over-stimulating for very sensitive skins and because of its texture and natural oilness it is apt to get dirty rather easily. These last two properties also mean that woollen materials must be washed carefully to prevent shrinking.

Cotton does not entangle much air, and is a more rapid conductor of heat than wool. It holds perspiration in such a way that the water evaporates quickly and cotton garments worn next to the skin may give a sensation of wetness and chill if one has been perspiring freely. On the other hand cotton can be easily washed, and so is particularly useful for making top garments such as overalls and frocks.

Mackintoshed material is ' rubbered ' so that it will not let *in* water, but equally it will not let *out* air, and so is an uncomfortable material and gives one a sensation of stuffiness. Rubber pilches for babies are unsatisfactory because the rubber keeps in both air and moisture, so that the child gets too hot and the skin may become sore from wet napkins.

Artificial silk in its qualities is probably about halfway between wool and cotton, but it has one special advantage in that it lets through the rays of sunlight that are good for the body, and enable it to make its own vitamin D. from substances in the fat lying beneath the dermis.

Flannelette is a cotton material, fluffed up to entangle air and increase its effect in preventing rapid heat loss from the skin. It is, however, a dangerous material because it catches fire very easily, and unless a ' non-flam ' variety is bought flannelette should not be used.

The unwisdom of wearing tight garters, stiff collars, tight neckbands and belts, tight shoes and gloves, is understandable if one thinks of the way in which they may interfere with the circulation of the blood ; with the movements of breathing ; with the proper working of the muscles ; and with the functions of the skin. The colour of clothes is also of some importance, since according to the colour of a substance, so does it absorb or reflect heat-rays. White and light colours reflect heat, black and dark, alternatively, absorb heat-rays : and this probably explains why it has become the custom to wear light colours in the tropics and in summer, and conversely to wear dark clothes in the winter.

The Care of the Skin.

Washing is one of the pleasures that civilised people share with the untrained natives ; but we have the advantage of being able to use hot water and soap. All forms of bathing are excellent for the skin, because the tiny nerves in the skin are stimulated, and a good flushing of the blood vessels of the skin is produced. Warm water and soap help in removing greasy dirt, and the rubbing of the skin when drying the body again encourages good skin circulation. Most people do get a good skin circulation after a cold dip, but a few people seem not to be able to react in this way—getting blue and shivery after a cold bath—and for such people it is wiser to bath in warm water. If the skin is trained in early babyhood to react to cold water there is much less chance that later on a cold bath will produce ill effects. In the baby the training can be done, either by squeezing a spongeful of cold water over the child's back at the end of the bath time, or by daily lowering the temperature of the bath-water by one degree at a time, until finally the baby is having a tepid bath and thoroughly enjoying it. A dirty skin is probably not in itself a source of ill health ; though one can see that if the skin is very dirty the chances of an infected sore resulting from an unnoticed prick or scratch is greater. There is no question, however, that the person with a dirty skin and unwashed clothes is going to be a most unpleasant member of the community, as the decomposing sweat and oily secretion on the skin and in the clothing fibres produce a thoroughly nasty odour. Clean clothes, particularly underclothes, are therefore a matter of real importance both to oneself and to other people. At night it is better to wear clothes other than those worn during the day, not only for the sake of cleanliness but because by undressing and putting on different garments one is more comfortable and sleep is likely to be more restful. Care must be taken about airing sheets and underclothes after they have been washed, because if they are slightly damp the body may be chilled and illness result.

For the health of the hair, good brushing with a hard brush is probably the most important treatment. The friction of the scalp stimulates the circulation under the skin which is stretched tightly over the bone of the skull and so probably has rather a sluggish circulation as a rule. The activity of the oil glands of the hairs is also stimulated by vigorous brushing, and gives the hair that glossy look which is very different from the dull, scurfy appearance of unbrushed hair. Hair, like wool, takes up dirt readily and therefore requires washing.

Nails are formed by special horny cells of the epidermis, and serve as a most useful protection for the sensitive finger-tips, and for the toes. In the human being, the hands are used much more cleverly than are the corresponding front paws of any of the animals ; and, unconsciously, we learn as much about the world around us with our fingers, as we do with eyes and ears. The fact that we use the fingers so much means that the nails get dirty easily and unless nails are kept short this dirt is difficult to remove. Dirt in the nails is likely to be a source of infection of food if we touch it and even of ourselves if the nails make sore places on the skin.

Sunlight, Air and Ventilation.

Sunlight besides giving ultra-violet rays and visible light rays, provides heat rays, and heats objects upon which these rays fall. This warming effect of the sun on the skin is pleasant and useful but a certain amount of care must be taken in exposing the body to sunlight. Heat from sun rays on the head and neck may be exceedingly injurious and produce the dangerous symptoms of sunstroke, also it is foolish to expose large areas of the skin to the sun for more than a few minutes until the skin has become 'tanned.' The browning effect on the epidermis of the skin produced by the sun is a means of preventing certain of the rays penetrating to the underlying capillaries and creating an inflammatory condition. Sun-bathing is excellent; but only when the skin has become tanned. The stimulating effect of sun on the skin and that of fresh warm air blowing on it is undoubtedly beneficial; but the skin must be acclimatised to such treatment. The dark skin of the natives of Africa and India is a natural protection from the sun.

Rooms that are sunny for at least part of the day are likely to be healthier than rooms that are badly lighted, or which are never reached by direct rays from the sun. Not only has the sunlight a cheering and stimulating effect on mind and body, but light rooms are likely to be much more germ-free—partly because germs are destroyed by direct sunlight and partly because one sees any dirt or dust in the room and can remove it.

From what has been said about the need of the body for oxygen and of the need of the skin to be able to lose heat, it is clear that the condition of the air in a room is likely to be a matter of considerable importance to our health and comfort.

What is required indoors is a continual supply of fresh air bringing us oxygen and sufficient movement of the air to remove the warm moist layers near the body which tend to reduce satisfactory heat loss. At the same time the air must not be so cold nor the movement so quick that the skin (and so the body) feels chilled. This latter problem is not likely to occur in the tropics, on a hot summer day in England, nor in hot crowded rooms. In the main, our usual difficulty is to ensure an entrance of fresh air and an exit of warm, moist air, without draught. The supply of fresh air and the removal of used air is usually termed ventilation and in most English houses ventilation is effected by simple devices, which if used sensibly can keep each room fresh and airy without much difficulty.

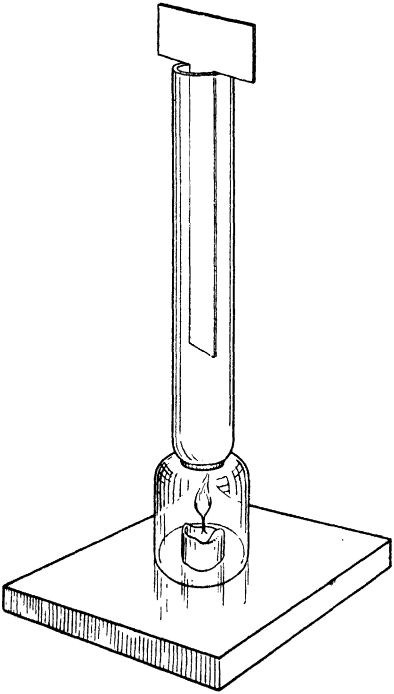
Fig. 26 : Diagram illustrating experiment with lamp-chimney and candle.

To get a proper entrance of fresh air and a removal of used air there must be at least two openings in the room, otherwise the replacement of the air already in the room by fresh air from outside is very slow, since it can only be brought about by a gradual diffusion of the one to the outside and of the other, inwards. A simple experiment will show the value of two openings (*Fig.* 26). Light a piece of candle about one and a half inches long and cover it over with a lamp-glass. The candle flame gradually flickers and dies out, since it is using up the oxygen in the air more quickly than fresh air diffuses in from the top opening. Remove the lamp-glass, and cut a T-shaped piece of cardboard to fit on the top of the chimney, so that the downward limb of the T hangs down about two or three inches and divides the chimney into two at the top. On relighting the candle and replacing the chimney with the cardboard partition in place, the candle continues to burn quite satisfactorily. A piece of smoking paper held over the top of the chimney will probably show that the smoke passes down one side and so this is the inlet for the cool fresh air and that the other half is the outlet for the smoke and the warm air rising from the candle.

Normally, in every room there is a door and an opening window, so that actually to start with there is a possible outlet and inlet ; and, as most rooms also have a chimney, the problem of the entrance and exit of air is not a difficult one, so long as we can use the openings in such a way that there is no draught while people are sitting in the room. It is much better if the exits and entrances communicate directly with the open air and thus a chimney is better than a door. The present method of building houses without chimney-stacks because no coal fires are used for heating is to be deprecated. Any opening will be at one time an inlet, and at another an outlet ; but it is usually possible to arrange for the proper utilisation of the openings to the greatest comfort of the occupants. The chief thing to remember is that warm air gets lighter and rises, and that we ourselves breathe out air which is warmer than the fresh air coming into a room ; consequently fresh air that is cold tends to form a downward current, while expired air from breathing tends to ascend. The same fact determines the upward draught of air in a chimney when the fire is lighted ; and at such times the chimney is the natural outlet in the room, and air probably comes in by both door and window. A sash window can provide two openings, and if one wants to prevent the sudden downward rush of cold air that the upper opening tends to produce, one can lift the lower sash alone, and if one puts a wide piece of wood between the frame and the lower sash, or in front of the lower sash, this gives the cold incoming air an upward direction first, and thus reduces the chance of a chilling gust of cold fresh air. Incoming fresh air is often cold and it is usual to put a heating radiator just in front of the window, so that the air is warmed as it enters. When one is in bed and warmly covered, a good current of fresh air all round the room is one of the best ways to ensure that sleep will be sound and refreshing and that one will not wake with a headache.

Bigger buildings, lecture halls, theatres and cinemas are difficult to ventilate ; and, as a rule, ventilation cannot be left to chance. Special ventilating devices or fans have to be used to ensure the comfort of the people in the building. Fans can be used in a variety of ways. In a large building a fan may be placed in a great shaft connected to all parts of the building. The fan may rotate in such a way that it extracts the moist, stagnant, warm air out of the building into the shaft, and so draws in cool fresh air from outside through various inlets. Sometimes a fan rotates to force fresh air along ventilating shafts into the building. In smaller rooms, in hot restaurants, and in tropical houses, fans are used to cause a general movement of the air. This movement of the air affords relief to the people in the room by moving away from the skin the layer of moist air which has prevented adequate loss of heat by heat conduction and evaporation of sweat.

It is true that lack of oxygen is fatal, but under normal circumstances no room or hall is so crowded that there is a serious reduction of the oxygen in the air. As a rule people in crowded rooms feel faint or get headaches, not because of injurious substances in the air or because there is too little oxygen, but because the stagnation of the air has allowed a hot moist envelope of air to collect around the body, with a consequent interference with heat loss. The circulatory system is affected and the supply of oxygenated blood to the head is reduced, with a resulting throbbing sensation or an actual loss of consciousness. The fact that a person falls down when in faint is a useful physiological reaction, because when one is on the ground the heart no longer has to drive the blood up against the force of gravity to the brain and when one is in the recumbent position an adequate supply of blood can reach the brain cells. A person who feels faint should put the head between the knees or actually lie down on the floor, and thus assist the heart pump to supply oxygenated blood to the brain.

The Care of the Bowels.

A regular action of the bowels is an important factor in maintaining good health. When peristalsis is sluggish the contents of the intestines are only slowly moved towards the rectum. Chemical changes, due to bacteria, probably produce an abnormally large quantity of poisonous substances; and, at the same time, there is a longer period for the absorption of any toxic material that may have been formed. Such substances are likely to disturb the body in a number of ways, and may result in a lowered resistance of the body to disease. In constipation there is usually a lack of that sense of well-being characteristic of good health: there is depression, and frequently some discomfort, and it seems unlikely that these particular symptoms are due only to the absorption of toxins, since immediate relief is often experienced when a bowel-action takes place. It is known that the internal organs are very sensitive to conditions such as swelling and inflammation, which cause pressure or pull on them. It may be that, to some extent, the unpleasant symptoms of constipation are nervous in origin and are due to distension and pressure in the abdomen caused by accumulation of gases and uneliminated bowel contents.

The first emptying of the bowels occurs shortly after birth. This primitive reflex action is not difficult to connect with the events of daily life in babyhood; and it is possible to establish bowel-action as a conditioned reflex associated with the taking of food at certain times of the day or with some other routine event. A habit which is an advantage throughout life is thus gained for the child whose mother or nurse takes the trouble to train the bowels to a daily action during babyhood. To the habit of visiting the lavatory at the same time every day should be added that of eating food which will help peristalsis. Fruit, brown bread and other foods containing roughage are particularly useful in this respect. A sluggish intestine is sometimes due to a lack of fat in the diet or to an insufficient quantity of liquid to drink, and constipation can often be cured by intelligent alteration of the diet. Exercise seems to play a part in aiding the regular action of the bowels; probably because, not only has exercise a tonic effect on circulation generally, but because after exercise peristalsis is improved.

The continued use of mild laxative medicines (although they are not in themselves particularly harmful) can establish a new conditioned reflex, with the result that the bowels do not act without the stimulus provided by the daily dose. This seems an unnecessary expense and bother in order to promote what should be a normal physiological function. Strong purgatives may so disturb the normal work of the intestines that days may elapse before ordinary activity begins again.

It is generally considered normal for the bowels to act once in the twenty-four hours; and every effort should be made to educate the bowels to such a habit during infancy and childhood. There is, however, probably nothing particularly essential to health in this time interval, and, in some individuals, the bowels may act more or less often than this with no apparent ill effects.

Each habit in life, including that of the action of the bowels, is dependent upon an association with certain routine events. One can see, therefore, that if the routine changes, as it may do by a change of work or during a holiday, some habits may be upset. One knows from experience that the bowel-action habit is in many people easily upset; and it is therefore wise when there is a change of routine, to pay special attention to the factors of diet and exercise which help bowel-action. It should be remembered, however, that there is no cause to be worried if, for a few days, the regular rhythm of the bowels is disturbed.

CHAPTER XIX

DUCTLESS GLANDS AND REPRODUCTION

In describing the ways in which the various activities of the body are brought about, something has been said about glands. The salivary glands, for example, send saliva into the mouth; and the sweat glands, secrete water on to the surface of the skin. The secretions of these glands are passed out, through special channels called ducts, directly to the places where they are to be used. But there are other glands and groups of cells which make secretions having remarkable effects, but which are used at places in the body quite isolated from the glands that make them and, sometimes, at many different places. From these glands the secretions, which their cells have manufactured from materials brought to them by the blood, are sent back into the blood stream and carried round in the circulation so that they can reach any part where they are needed. The actual organs or groups of cells which make these *internal secretions*, as they are called, have no ducts and so are sometimes called the ductless glands. It is better however to call them the glands of internal secretion, or—using the word coined from the Greek (*Endo*, within; *krino*, to separate)—the Endocrine glands: because this will include those which have no ducts (suprarenal, thyroid and pituitary glands); and those which occur as groups of cells inside organs which have ducts through which other substances made in them are passed out (pancreas, ovaries, testes).

Of this latter group the pancreas is a good example.

It has already been considered as a gland which, through its duct, pours out into the small intestine, a very active digestive juice. Within the gland there are special groups of cells, called *islets*, which do something quite different and very important. They make an internal secretion which enables the cells of the body to use sugar. Unless the body can burn sugar it cannot live properly nor can its muscles do any work.

The sugar-story in the body is a queer one. Sugar is so necessary for life that without it we die; but we also die if too much of it is being turned into the blood. During digestion, as we have seen, sugar and starch taken in as food are passed into the blood in the form of simple sugars. For the tissues to be able to live, sugar has to be carried to them by the blood. The amount in the blood has to be kept within very narrow limits and there is serious trouble either if there is too much or if there is too little. Now we get our supplies of sugar intermittently, either at meal times, or perhaps between meals, when as sometimes so pleasantly happens the rules for good feeding are broken and sweets are eaten. This fluctuating supply to the individual has somehow to be changed into a steady one for the tissues, and this is done by the liver and pancreas working together.

The sugar, after it is absorbed from the intestines, is passed directly to the liver, where with the help of the internal secretions of the pancreas, it is stored in the liver cells in an insoluble form as glycogen. As and when sugar is needed in the body, the glycogen is turned back into sugar and sent out from the liver to be distributed in the blood to the parts of the body needing it. Too much sugar in the blood is so harmful that it is turned out as quickly as possible by the kidneys. This happens in the disease known as *diabetes*, in which the islets of the pancreas are not working properly and the liver is not able to store the sugar as it comes to it from the intestines but passes it straight on to the circulating blood.

For about fifty years it had been known that the way to help people suffering from this disease would be to get hold of this internal secretion from the pancreas; but, though many people were trying to obtain it for a long time there was no success. Then, in 1922, two Canadians named Banting and Best, working in the Physiology Laboratories of Toronto University, found out how to get this precious substance from the pancreas of slaughter-house animals; and because it came from the islets it was called *Insulin*. When diabetics are given insulin they can use sugar and are able to take enough food to live a normal life. It cannot be given by the mouth because it is destroyed by the digestive juices and therefore it has to be injected. It is so powerful that sometimes after a dose, sugar is used up so quickly that the blood has not enough and very serious symptoms are produced. To remedy this sugar has to be eaten. Diabetics who live a long way from doctors and hospitals and grocers and sweet shops, and have to inject insulin themselves, always carry about packets of sugar which they can eat at once if they feel the symptoms of "too little sugar" come on. It is wonderful to think that these little groups of cells, so small that they can only be seen with the help of a microscope, nevertheless have such a powerful effect on the body.

Extraordinarily widespread actions are due to two other very small endocrine glands, which are found placed like little caps one above each kidney. They are called the *adrenals* or *suprarenals*. Together the glands, on the average, only weigh about one-third of an ounce, yet they manufacture secretions of very great activity; and one of these, known as *adrenalin*, can be prepared in the laboratory, and its actions in the body have been very fully investigated. Its value appears to be that it prepares the body physiologically for a crisis. When adrenalin is poured from the glands into the blood stream, the heart beats more quickly, the blood pressure is raised, and there is an improved circulation through the muscles. The liver quickly turns more of its stored glycogen into sugar, and so more sugar is brought to the muscles; and the body is then prepared either for a fight or a flight! The digestive processes are temporarily held up, so that more blood is available for the emergency organs. The pupils of the eyes dilate as they do for the same reason (i.e. outpouring of adrenalin from the glands) in anger or fright, and so make the eyes look bigger. In a furry animal, such as a cat or dog, the muscles attached to the hairs contract and the hairs stand on end making the animal look much larger and so more dangerous to attack. We cannot alarm our enemies in this particular way, but all the other changes take place and, though we have no fur to stand on end, we still show the actions of the adrenalin on the muscles of the hairs by a condition of the skin known as 'goose flesh' and a sensation in the scalp which has been described as making 'each particular hair to stand on end like quills upon the fretful Porcupine.'

One of the most important of the endocrine glands is the thyroid. This gland lies in front of the windpipe, but we do not notice it unless it swells and produces what is called a goitre. Its secretions are important throughout life, but especially so in the earlier stages, because without it a baby cannot grow into a normal human being. This connection between the thyroid and growth was discovered about fifty years ago. Before that time a baby born without a thyroid had no chance of becoming a normal person. Instead it developed into the grotesque and tragic figure known as a *cretin*, a creature stunted in body and mind. Now, as a result of using thyroid, something very much in the nature of a miracle takes place ; and the undeveloped child changes and grows into a perfectly healthy normal individual ; but the treatment has to be continued throughout life. Luckily this active principle is not destroyed by the digestive juices and the thyroid (usually sheep's gland) can be taken by the mouth.

Sometimes, and this is particularly the case just before adult life is reached, the gland becomes too active, the heart beats very quickly even during rest and its rate goes up too much after quite moderate exercise. If this happens a doctor should be consulted, because with proper treatment and rest and plenty of fresh air the condition is soon corrected and the body brought back to the normal again.

An odd thing about this thyroid secretion is that it contains quite a lot of iodine. Only very small quantities of iodine are taken in the food; but this is carefully picked out and stored away in the gland, for if there is too little iodine the gland cannot act properly. In a country like ours where no districts are very far from the sea—which is the great source of iodine and where seaweed manures are available—there is generally plenty of iodine in the vegetables. But even in this country there are counties where thyroid-enlargements are common, and ' Derbyshire neck ' is a very well-known condition. In big continental countries there are regions in which all sorts of thyroid trouble are common. In some parts of Switzerland cretins used to be fairly common, and even a few years ago in some cantons nearly eighty per cent. of the school children showed enlarged thyroids until they were given iodised chocolate or salt, after which very few cases occurred. The same has been found in America round the Great Lakes.

The thyroid is not only important for human beings and the other mammals but also for many other animals. For example, trout living in streams contaminated with sewage develop goitre, as do humans who drink contaminated river-water. Even creatures like tadpoles depend upon their thyroids, for without thyroid and without iodine their metamorphosis into frogs cannot take place.

Some dwarfs, as has been said, are deficient in mind as well as body due to lack of thyroid; but there are other dwarfs, who, though they remain quite tiny like 'Tom Thumb' because their skeletons have not grown properly, are quite normal mentally. This kind of deformity is due to an insufficient amount of the secretions of yet another endocrine gland, the pituitary. This organ which is about the size of a pea is to be found at the base of the brain to which it is attached by a kind of stalk. If it makes too little of its internal secretions, the individual is a dwarf, and if too much, a person becomes a giant. Other secretions produced by it play a very big part in the development of sex by influencing the two organs which are finally responsible for making human beings into men and women.

The years between about twelve and eighteen are for all boys and girls a time during which the ductless glands are of especial importance, because, not only do they regulate healthy normal growth in size, but because some are responsible for all the physical alterations which change the boy into a man and the girl into a woman.

There are so many differences between the child and the grown man or woman that it is difficult to think of them all at once; but they are nearly all of them connected with the development of a new function and of the growth of the mind and body to fit the man or woman for that function. It will be remembered that all living material, besides being able to eat, and breathe, and excrete and respond to stimuli, possesses the power of being able to make new organisms, so that the particular kind of animal or plant shall not die out. This ability to produce new individuals is termed *reproduction ;* and, in common with all the living world, human beings also possess the power of reproduction.

The very simplest organism like the amœba, in which one cell is the 'person' and performs all the different functions of life, produces new amœbæ very simply. At some moment the nucleus of the amœba divides into two and round each half of the nucleus some of the cell-cytoplasm collects, and where there was originally one amœba there are now two and the parent has disappeared in making the new individuals. This simple type of reproduction is not found in plants and animals made of many cells and with a more complicated structure. In such organisms, different cells in the plant or animal carry out different functions: some cells specialise in digestion, others are concerned with taking up oxygen and yet others with excreting, whilst some of the cells are responsible for reproduction. For the formation of a new organism it is necessary that the reproductive cell of one parent organism should unite with the reproductive cell of another parent organism; and from the two united cells the new organism grows. This union of the reproductive cells is termed *fertilisation* and is the necessary stimulus for the production of a new individual of the species. It is interesting to find that even in quite simple plants and animals the reproductive cells are of two types and that reproduction can only occur when union takes place between two different cells. Much the same kind of difference is found to occur in the reproductive cells of all plants and animals, whether quite simple organisms or very complex and highly developed ones. One set of cells are usually very small and active, and usually have to find the other cell, which is larger and provided with a supply of food-material for the growing new individual. When the two kinds of cells are produced from different individuals, those who produce the tiny cells are called the males and the reproductive cells are termed (in the animal world) the *sperms*. Those whose reproductive cells are larger are the females and the cells are called eggs or *ova*.

In animals like frogs and fish the parents have no responsibilities. The male frog or fish deposits sperms in the water near the eggs from the females, either as they leave her body or soon afterwards ; and the fertilisation of the ova is a matter of chance. Because the chances of fertilisation are somewhat remote, large numbers of eggs are produced so that it does not matter if a good many are never fertilised. In the Spring, ponds are often a mass of frog-spawn, which is the collection of eggs formed by the female frogs. Higher up in the animal scale of development the processes of nature are less wasteful : the male deposits the sperms within the body of the female and the chances that fertilisation will occur are thereby greatly increased ; and correspondingly fewer egg cells are produced. In birds the egg is laid with a hard shell which is protection for the chick bird until it is sufficiently developed to peck its way out. The hen and cock birds share the responsibility of building a nest, of keeping the eggs warm, and of feeding the young until they can fly.

The next step in the care of the growing young animal is a very important one. In animals like rabbits and cats the fertilised egg remains inside the mother's body and there the single cell made by the union of the two reproductive cells grows into a more or less complete young animal. It gets oxygen and food from the mother's blood during this time, and only leaves the mother's body when it is able to some extent to fend for itself. Even so it is dependent upon its mother for food for some time after birth and is fed with milk from her special milk glands. The milk glands are called *mammary* glands ; and this method of feeding the young has given the name to the very large group of animals (*mammals*) who have in common the characteristic of suckling their young with milk from the mother's mammary glands. Human beings are mammals, and for several months after a baby is born its natural food is milk from its mother's breasts (mammary glands).

Because the process of fertilisation (*mating*) and of growth in the mother's body (*gestation*) is such a highly developed function, the reproductive organs are rather specialised structures.

In the man there must be the organ for making the sperms, and the means by which the sperms can be placed near the egg-cell so that fertilisation can take place. The sperm-making organs are the two *testicles* which lie outside the body-cavity between the legs and are contained in a bag-like structure, the *scrotal sac.* The testicles really consist of a large number of very tiny tubes in which the sperms are formed. From each testicle is a long tube (*the vas*), which leads up into the body cavity and along which the sperms pass. The vas from each side opens in the mid line into the urethra, and this passes through the middle of the *penis,* which lies outside and over the testicles. The sperms are continually being formed during adult life. With fluid from the *prostate* and other glands the sperms form the semen and this is passed periodically from the body, sometimes during sleep. The penis is a mass of connective tissue, together with a little involuntary muscle and many large dilated capillary spaces. Normally the organ is soft and flaccid ; but these blood spaces can become filled with blood, swelling the penis so that it becomes erect and hard, and can be introduced into the vagina of the female, where the semen is deposited. In addition to the tubules of each testicle, there are small groups of cells lying between the tubules and these probably form an internal secretion which is responsible for those obvious changes in the boy when he is reaching manhood. These changes include considerable muscular development, growth of hair on face and body, and a lengthening of the vocal cords which causes the voice to deepen. These various changes which occur in the boy and those which occur in the girl take place more or less slowly over a number of years during a period which is called *puberty* or *adolescence.*

The changes which occur in the girl are somewhat more complicated, because the reproductive function in the females of mammals includes not only the formation of the reproductive cells, but also the nourishment of the growing young within the mother's body and the feeding of the young by the mammary glands after the young are born.

The egg-forming organs in a woman are the two *ovaries*. These lie low down within the body-cavity, one on either side and each ovary is about one and a half inches long and half an inch thick. Close to each ovary lies the funnel-shaped opening of a tube. These two (*Fallopian*) tubes open at the other end into the same small hollow muscular organ, the *uterus* or *womb*. The womb is a pear-shaped organ about three inches long and one inch thick, with its wide end upwards, where it is about two inches wide. The lower narrow end opens into a tube about five inches long, the *vagina*, which in its turn opens on to the external surface of the body between the opening of the urethra and the anus. During childhood the ovaries contain only many immature ova, and some begin to develop at puberty. The development consists in a growth in size of an ovum itself and in the formation round it of a casing of other cells together with some liquid (*follicle*). This follicle gets larger and gradually extends to the surface of the ovary. Then the casing breaks and sets free the ovum, which is caught by the funnel-shaped mouth of the Fallopian tube along which the ovum passes.

The womb is the hollow shelter in which the fertilised ovum rests and develops during nine months, and as soon as the ovum is set free from the follicle the soft lining of the womb begins to thicken and its blood supply increases, in preparation for the ovum, should it be fertilised.

These changes in the uterus are not needed when there is no fertilisation, so that about ten days after the ovum is set free the thickened lining disappears. The tiny blood vessels in the soft coat get broken as the lining gets normal again and bleeding occurs. Blood and mucin pass away from the womb through the vagina and this flow produces the first *period* or *menstruation*, as it is called.

Menstruation usually lasts about four or five days. About two weeks later another ovum is set free from a follicle and ten days later another menstruation occurs. This periodic monthly flow usually continues for some thirty or thirty-five years.

Menstruation is thus a normal function of every healthy girl and like so many of the activities of the body is periodic. In the case of the heart, the beat occurs about seventy times a minute; we breathe seventeen times a minute; we eat at about four-hourly intervals during the day; whereas the bowel is only active usually once in the twenty-four hours. The intermittent activity of the ovaries and the womb is only different from many of the other functions of the body in that the activity occurs only once in four weeks, and there is no justification for looking upon menstruation as an illness. It is in fact the sign of a normal, healthy functioning of one system of the body.

However, like all the processes that occur in the body, the event needs to be treated with good sense ; and in this particular case, unless a girl is careful that all the rest of her body is functioning adequately during the period, she may suffer discomfort or even pain. Discomfort can usually be prevented by taking special care in one or two directions ; and, as there is no reason why in a healthy girl there should be pain, a doctor should be consulted if periods are times of pain. It should be remembered that menstruation indicates that the womb is in a slight state of congestion and such a condition is often relieved by improving the circulation. One of the best ways of 'brisking-up' the blood flow all over the body is by exercise. It is therefore wise just before and during the period to be sure that daily exercise is taken, provided it is the amount and kind of exercise one is accustomed to take between the periods. To make a point of lying-up and of resting a great deal during the period is, for a healthy girl or woman, one of the most likely causes for discomfort and pain.

The circulation is also improved by baths ; and to take the usual daily cold or hot bath is as important as exercise at the period ; and for the sake of cleanliness and wholesomeness it is obviously particularly necessary to wash the surface of the body at such a time. Moderation and common sense are the best guides to healthy living and to take excessive exercise or unusual kinds of baths, with the risk of chill during menstruation is as foolish as it is to rest unduly or not to wash at all. Since pressure against a slightly congested organ is likely to cause discomfort or pain, and the rectum lies just behind the womb, special care should be taken just before and during the period to ensure that there is adequate bowel action.

As in the case of the testicles in the boy, the ovaries secrete hormones which are responsible for the characteristic development of a girl during puberty. These changes include a widening of the pelvis and a growth of the breasts—both changes which are necessary to adapt the body of a woman for motherhood.

When the ovum in its passage down the Fallopian tube meets a sperm and becomes fertilised, instead of leaving the body as does the unfertilised ovum, it comes to rest in the wall of the womb and the whole nine-months growth of the developing child (*fœtus*) takes place inside this cavity. During this time no new ovum is set free and menstruation ceases. The developing fœtus receives its nourishment from the blood of the mother. A special structure called the *placenta* is formed in the wall of the womb and the fœtus is attached to it. In the placenta the blood of the mother is only separated from the blood of the fœtus by a very thin layer of cells. This separation prevents a mixing of the mother's blood with that of the fœtus ; but oxygen and materials in the mother's blood can pass through the cells into the child's blood, and into the mother's blood pass carbon dioxide and other unwanted substances made by the growing child. The cells of the placenta protect the child's blood from most poisons and micro-organisms that may be in the mother's blood and there are very few injurious materials that can reach the child from the mother's body. As the child grows, the womb stretches and the muscle lengthens and strengthens until finally when the fœtus is sufficiently developed the muscular walls contract rhythmically and expel the child out of the womb through the vagina. During the weeks of pregnancy the mother's breasts prepare for suckling, and after birth for many months the baby's natural food is the mother's milk, which alters in composition to suit the varying needs of the growing child.

When the sperm and the ovum unite, the essential part of each cell that fuses is the nucleus. Within each nucleus are minute granular bodies (*chromosomes*), which we believe to carry those characteristics of the parents which make the young of each species like the species in general, and the parents in particular. This characteristic of heredity is a factor of first importance in determining the kind of body and nature that a child will have. Healthy parents are likely to produce healthy sperms and ova, and so have healthy children. It must be remembered that the chromosomes carry not only the known characteristic of the parent-cells, but often the hidden characteristics that they have inherited from their own parents; and so each child represents some of the many characteristics of all its ancestors for numberless generations. Children of a healthy stock thus start with a big advantage, and can withstand adverse conditions during babyhood and childhood that would have quite serious effects upon children of less robust parents and grandparents.

Growth is determined primarily by the particular branch of the human race to which an individual belongs. There are well-recognised limits to growth and the stories about tiny people only as large as flowers or enormous persons as high as trees are truly only fairy stories. Similarly, within the races and tribes there are well-known types of growth. Most Northern European people are tall and large-boned, whereas races like the Japanese are usually small-made people.

Thus every child starts life with certain tendencies for smallness or largeness which depend upon its heredity. Growth however can be greatly influenced by special conditions affecting the body and the first of these influences is the health of the mother during the months before the baby's birth and while she is feeding the baby with her milk. During that time special care should be taken that the mother gets plenty of fresh air and exercise, good restful sleep and adequate food. It is the quality rather than the quantity of food that matters, since it is upon the mother that the child depends for essential amino acids, for calcium, iron and phosphorus and for vitamins —all important influences on growth. Children are affected more disastrously by unhealthy conditions than adults: probably because their food has not only to make good wear and tear but, since the cells increase in number, it must also make new tissues. In general all the conditions of everyday life that are important for health should be more specially provided for children than for the grown-ups. Once children understand why certain things are good and why others are unwise they can save a great deal of bother for everyone by taking care that their own way of living is healthy.

Without good health most things in life are spoilt, and once we know the *why* and *how* of our bodies there is no reason why we should spoil things by having ailments that are due to unwise habits.

CHAPTER XX

THE HEALTH OF THE COMMUNITY

On reading the histories of any people such as those of the Greeks, the Romans, and of the peoples of modern Europe, we always find that to a lesser or greater degree rules are made to improve the health of the community; and individuals are expected to obey these rules since healthy units make a healthy whole. This has been the case even among the more primitive races.

Before the enormous strides made during the nineteenth century, in our knowledge of science and medicine, many of the rules had been laid down, not because the people understood why they were good, but because it had been found by experience that in the absence of such rules ill health occurred or diseases spread. Fortunately we live in a time when the workings of the body and the causes of ill health are so much more accurately known, that the reasons for the laws that are made and for the plans adopted to secure communal good health and happiness are generally understood and accepted, and most of us try to co-operate in making them effective. Perhaps the most striking thing about present day Public-Health measures, is the fact that they aim primarily at the prevention of ill health. It will be a long time, if ever, before disease is stamped out, but the battle against it can be fought by striving to possess good health. Measures which prevent disease, Preventive Medicine, are as important as those which treat disease, Curative Medicine.

One of the very noticeable differences between the Middle Ages and the present day, is the absence of the terrible epidemics that in those days used to carry off great numbers of people. In 1349, the Black Death in England wiped out about half the population and the four millions were reduced to two. In 1665, Sir Tobie Matthew wrote of the Great Plague, "I think the reason why the Plague is somewhat slackened is because the place is dead already and no bodie left in it worth killing." Smallpox and typhus alone caused the death of hundreds yearly. In Great Britain now, there are astonishingly few cases of smallpox and these usually among the unvaccinated. Typhus, a disease due to dirty conditions and spread by vermin, has been practically stamped out in this country.

Such improvements can only occur if we take advantage of the information provided for us by scientific research. We now know that the so-called infectious diseases are spread from person to person, sometimes by direct contact with a diseased person or by contact with clothes and utensils touched by such a person; sometimes by lice and flies and dirty food; and sometimes by infected water or milk. Once having learnt the ways in which infection is spread the problem of the prevention of a disease and of epidemics is a matter of education and is in our own hands.

The prevention and cure of disease has been greatly helped by our knowledge of the forces used by the body in its fight against germs. In many cases the white corpuscles attack and engulf the germs, but the body possesses another method of combating an infection. It can develop substances (anti-toxins) which will 'neutralise' the poisons (toxins) set free by the germs.

When an individual is not susceptible to infection by a particular germ that individual is said to possess *immunity* against the disease. This immunity may be natural or acquired. By natural immunity is meant the power of the individual from birth to withstand the infection. Sometimes whole groups of people or kinds of animals are naturally immune to a disease. Negroes seem to be immune to yellow fever and sheep are immune to tuberculosis (although oxen and cows suffer from this disease). An acquired immunity from a disease is gained as the result of either one attack of the disease or numerous small infections which do not succeed in producing a recognised attack of the disease. The presence of the toxin seems to stimulate the body to produce an increased quantity of anti-toxin, and, when the battle against an infection has been won by the removal of the germs and the neutralisation of the toxin, the resistance of the body to that particular disease is greater than before. The body has thus acquired an immunity that may possibly last for life.

In 1789, when smallpox was still a devastating plague in this country, Dr. Jenner observed that cowherds and milkmaids did not share with other people the liability to smallpox. He discovered that on the udders of cows there were often spots not unlike those of patients suffering from smallpox, and that the hands of the milkers also often showed similar spots. He thought that perhaps this meant that the cows were suffering from a kind of smallpox and that they infected the milkers, who also had a sort of local attack. It was known that people who had had one attack of smallpox and had recovered, practically never had another attack and it was suggested to Jenner that the slight attack of 'cowpox' given to the milkers protected them against the more virulent variety then so prevalent.

Acting upon this idea, he proceeded to give this mild local 'pox' to his own child, by rubbing into a scratch on the skin some of the fluid from a spot on a cow's udder. He found that after the mild attack the child could withstand inoculation with fluid from a pustule from a case of the virulent type of smallpox. After continued experimenting it seemed quite evident that his theory was a true explanation of what occurred, and that an attack of ' cowpox ' was as good a method—and a far safer one—of acquiring immunity against the human virulent variety, as was a previous attack of the disease. This way of deliberately obtaining immunity against smallpox constitutes *vaccination* and has been in use ever since. Jenner found that the fluid from the cowpox spot of one human being was as useful as the fluid from the spot on a cow, and at one time therefore ' arm to arm ' vaccination was common. It is now realised such a method is not satisfactory and vaccination is practised with surgically clean cow-lymph so that if the operation is done under proper aseptic conditions the patient receives nothing except the smallpox-virus. It should be realised that vaccination can only give immunity to smallpox and to no other disease, for each disease has its own particular toxin and anti-toxin.

Vaccination in most cases only produces a local infection with no general ill effects; but occasionally there are individuals in whom the response to vaccination is severe, though even in these cases serious consequences are unlikely to occur. Nevertheless most thinking people believe it right that we should all be vaccinated, so that the whole community may become immune and smallpox will be stamped out. Serious consequences from vaccination are much less likely to happen in infancy; and it is therefore best to have a child vaccinated before it is a year old. The length of time of immunity from smallpox, conferred by one vaccination, varies; and, to be on the safe side, it is wise to re-vaccinate several times after babyhood, over the first thirty years of life. Since one vaccination protects against serious consequences from any re-vaccination, this is another reason why it is wise to have the first vaccination done during infancy. There also seems no doubt that vaccination, even if it does not always give continued immunity from smallpox, does greatly reduce the severity of an attack should a vaccinated person become infected.

Everyone connected with a smallpox hospital—doctors, nurses, attendants and tradespeople—are all vaccinated; and although very serious cases of the most virulent type of smallpox come to the hospital, no one serving a smallpox hospital has ever had the disease.

The prevention of disease is a matter of common concern and since the value of vaccination as a means of preventing smallpox is generally accepted by the community, free vaccination is part of the Public Health Services.

The immunity obtained by vaccination is presumably brought about by the large excess of anti-toxin developed during the local attack produced by the cowpox-virus. Several other diseases are treated in a similar way and inoculation is now a recognised weapon in preventive medicine. The longest immunity is obtained by giving the person a mild attack of the particular disease, but a temporary immunity can also be acquired by inoculating with the anti-toxin itself. This form is the immunity obtained for diphtheria and, as it is the anti-toxin that is introduced, this injection can be used in the early stage of an attack of the disease itself to give the patient a strengthened line of resistance until his or her own anti-bodies have been formed.

Susceptibility to diphtheria can be ascertained by the Schick test, in which a small dose of diphtheria toxin is introduced into the skin. A recognised skin reaction appears in a person liable to develop the disease on exposure to infection and such a person should be protected by suitable doses of anti-toxin.

The effects of a definite attack of an infectious disease are more serious during the period of growth and efforts should be made to protect children from infection, by deliberate immunisation where possible or by avoidance of direct contact with disease. X-Ray photographs of bones show that their development may be arrested by an attack of an infectious disease; and a severe attack of one of the common infectious diseases may leave a weakened heart or greatly reduce the power of the individual to resist infection from other diseases. It must be remembered that the ill effects that persist after an attack of a disease may heavily handicap the individual for the rest of life, so that living loses much of its joy and not only may that individual be of little use to the community but he or she may be a continued public responsibility and expense; and the health of that person's children be influenced adversely.

To prevent the spread of disease every case of one of the so called Notifiable Infectious Diseases must be notified to the Public Health Authorities, who can then arrange if necessary for the removal of the patient to an isolation hospital; for the disinfection of the room or house; and for the observation of people who may have been infected before the isolation of the patient.

Health can and should be our possession if we live in healthy surroundings. During the nineteenth century the growth of industry was so rapid that adverse conditions developed and were established before their danger to the community had been realised; so that one of our battles in preventive medicine is that of getting rid of conditions that are bad and of substituting better ones. A case in point is found in all our big cities, where there is overcrowding in buildings that are often airless, sunless and damp. It is true that such conditions are harmful to all, but they are terribly bad for the children; and, since the health of the children determines the health of the next generation of grown-ups, everyone who cares about Public Health looks upon the Housing Problem as of vital importance for the future of the country. As slum-areas are demolished, new houses must be built and it is the business of the community through its Ministry of Health and its Local Councils to see that these new buildings are not going to suffer from the defects of the old ones and that they will really be airy, sunny, warm and dry; and near open spaces and trees.

Public-Health measures may be considered from two points of view: (i) what the community does to keep its good health and improve the general standard of healthiness, and (ii) what the community does to cure disease and prevent its spread.

The first important Public Health Act in England was passed by Parliament as long ago as 1875; and since then other Public Health Acts, and Acts regulating conditions likely to affect the health of the community, have become the law. Such laws are concerned with the way in which houses are built; with the problem of house- and street-drainage and with the disposal of sewage; with the collection and destruction of domestic and street refuse; with the supplying of a sufficiency of pure water for drinking purposes and for cleaning purposes; with the way in which food is sold and the quality of these foods; with the cleanliness and health of cows and milkers and the sale of clean milk; with the notification to the proper authorities of cases of infectious disease and the isolation and care of sick people; with the health of the industrial worker and with the health of mothers, babies and school children.

Most of the Public Health services are free to the community and are paid for through the money collected by Parliament in taxes, and by the Local Authorities in rates.

Some of the most useful health measures that have been instituted in this country are those concerned with the health of mothers, babies, children and workers.

At an Ante-natal Clinic an expectant mother can get advice before her baby is born ; and from the time of its birth until it reaches school-age, both her own health and that of her baby is the concern of the Health Visitor and the Doctor of the Maternity and Child Welfare Centre she attends. Day-Nurseries, Creches, and Nursery Schools provide safety and care for babies and young children of mothers who are obliged to work outside the home. During school-years there are periodic medical inspections ; and children not in normal health, and those who are crippled, deaf, or blind are sent to Special Schools. Because we now realise how tremendously important to health is feeding, the Public Health Services look after mothers and young children in cases of real need. The help is given as additional food, either as free milk or milk at a reduced price for the mothers, or in the form of free dinners and free milk at School for the children.

The health of the workers is also looked after by the community and there are regulations for the proper ventilation, lighting and cleanliness of factories and work-places, and for reducing risks to health in certain unhealthy trades.

That the attention paid to the health of the community is indeed reaping its reward can be shown by a few examples. In 1899, the number of babies who died under one year, was 161 of every 1,000 babies born ; that is to say one in every six babies did not survive the first year of life. In the last report of the

Chief Medical Officer of the Ministry of Health the Infant Mortality Rate is given as 64—an improvement which means that only one in sixteen of the babies born fail to survive the first year.

Tuberculosis is still prevalent and must be considered a serious disease; but there are now few cases of 'galloping consumption' and few instances of all members of a family dying of this disease within a short period of one another. The improved health of the community has raised the average age at death by fifteen years. A new outlook in matters of health has been developed and the community realises the need for personal, domestic and public cleanliness and is less tolerant of bad hygienic conditions and of a slack Public Health authority. But a higher standard of healthful living still is required and only by persistent wise education can public opinion be trained to demand improvements.

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